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THE INFLUENCE OF STRESS ON PREDICTED MAXIMAL OXYGEN UPTAKE

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "The Influence of Stress on Predicted Maximal Oxygen Uptake," submitted by Sally J. Aldred in partial fulfillment of the requirements for the Degree of Master of Science.

ABSTRACT

Twenty-eight healthy female subjects in second and third year physical education at the University of Alberta were used to determine the influence of a test-induced stress on the prediction of maximal oxygen uptake as determined by the Astrand-Ryhming Nomogram and any variation of results which occurred with subjects working at a low work load, designed to produce a steady state heart rate of approximately 138 beats/min. and subjects working at a high work load, designed to produce a steady state heart rate of approximately 164 beats/min.

Four tests were administered to each subject over a period of 3 to 4 weeks. Each subject was assigned randomly to the low (Group I) or high (Group II) work load following an initial test and no previous indication was given that a stress would be administered in Trial 2. The test was performed on a Monarch Bicycle Ergometer until subjects reached a steady state heart rate close to 138 or 164 beats/min. after 6 minutes of exercise and heart rate was recorded at 1 minute intervals throughout the test. At the beginning of Trial 2, a pistol was fired once directly behind the subject's head. Work capacity was determined using the Astrand-Ryhming

Nomogram. Results were analysed with Pearson Product-Moment Correlation Coefficients, and a two way analysis of variance repeated on four trials, and a one way analysis of variance repeated on four trials.

Results obtained were: The mean steady state heart rates for all 28 subjects were: 149.73, 151.07, 147.29, 145.28. For Group I they were: 134.14, 138.86, 135.54, 133.07. For Group II they were: 165.32, 165.29, 159.04, 157.69. Statistical analysis indicated that there was a significant difference between the means over the four trials for Group II ($P = .01$). This difference was not between the control (trial 1) and stress (trial 2) trials, however, but appeared to be between trials 1 and 3, trials 1 and 4, trials 2 and 3, and trials 2 and 4.

Correlation coefficients between the four trials for all 28 subjects were as follows: 0.88** (2-3), 0.89** (1-2, 1-3, 2-4), 0.90** (1-4), 0.92** (3-4). For Group I they were: 0.39 (1-2), 0.47 (2-3), 0.50 (1-4), 0.51 (1-3), 0.61* (2-4), 0.73** (3-4). For Group II they were: 0.42 (1-4), 0.57 (2-4), 0.58* (3-4), 0.61* (1-3), 0.70** (2-3), 0.78** (1-2). (** Statistically significant at the .01 level; * Statistically significant at the .05 level)

Within the limits of the study, the following conclusions have been made:

1. For the population studied, stress appeared to have no significant influence on the prediction of maximal oxygen uptake as measured by the Astrand-Ryhming Nomogram.

2. Stress did appear to influence the mean heart rates during the initial period of exercise, however, this influence was abolished before the conclusion of exercise. This influence was more prolonged in the case of the low work load group.

3. Improvement in prediction occurred with repeated testing of the subjects. No attempt was made to differentiate between training and learning effects. Familiarization of the subjects with the test may have contributed to this improvement.

4. The reliability of this predictive test appeared to be higher with heavier work loads.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Exercise physiologists generally agree that the individual's capacity to perform long continued physical work in a temperate environment is limited by the combined capacity of the respiratory and cardiovascular systems to deliver oxygen to the working muscles (the maximal oxygen intake) (10, 39, 41, 54, 64). Accordingly, the maximal oxygen intake is a useful criterion for assessing the over-all capacity of an individual to perform aerobic work. Also, the accurate measurement of this efficiency is considered to be the best objective measure of physical fitness, as reflected by the cardio-respiratory system (13, 44, 51, 52, 68).

Various methods of assessing maximal oxygen intake have been developed (7, 51, 63, 64, 69). This measurement, when obtained under properly standardized conditions, has been shown to be a highly reproducible characteristic of the individual, having a coefficient of reliability of 0.95 (64).

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[illegible]

[illegible]

The test does have, however, certain impracticalities; it is time-consuming, and thus not commonly used in the study of large groups, it is complicated and costly in terms of equipment, it requires a high degree of cooperation from the subject, and it involves the potential risk of subjecting subjects to the stress of physical exertion sufficient to produce a maximal oxygen intake.

Several techniques have been developed to predict maximal oxygen intake from performance characteristics at submaximal work loads. Under carefully standardized conditions, in selected homogeneous groups, the pulse rate at submaximal levels of work is systematically related to the maximal oxygen intake (12, 74). Thus, the capacity to perform physical work can be estimated from study of the pulse rate at submaximal work levels. Indeed, Astrand and Ryhming (12) have constructed a nomogram which rests upon this postulate. The maximal oxygen intake is predicted with this nomogram from a single measurement of oxygen uptake and pulse rate at a submaximal work load.

A number of investigators have compared the values obtained on the Astrand-Ryhming nomogram and values obtained by direct measurement, and reported high correlations between predicted and actual values (12, 30, 27). Glassford (36), in a recent study, compared the Astrand-

Ryhming predicted values to those found directly by three of the more commonly used tests of this capacity. He found that the relationship between the nomogram values and any one set of values determined by a direct technique was as good as the relationship between the values of any two direct measures examined in that study.

There are serious limitations, however, connected with the use of heart rates at submaximal work loads. There are a large number of physiological conditions which will alter the work pulse rate, and thus rigid standardization is necessary if the results of the procedure are to be interpreted in terms of work capacity.

These factors include the degree of physical conditioning (26, 57), elapsed time after the previous meal (48, 65), total circulating hemoglobin (14, 45), the degree of hydration of the subject (1, 24), alterations in ambient temperature (23, 32, 65), hydrostatically induced changes resulting from prolonged erect posture (3, 32, 65), fatigue (65), mechanical efficiency (32, 47), and the emotional state or degree of excitement of the subject (57, 65).

If such a predictive test is to have practical application, the influence of such factors on the test must be examined. Many of these factors have been care-

fully investigated. The question of whether stress and excitement alter the prediction of maximal oxygen intake, however, is the factor which most requires deeper investigation at the present time.

Statement of the Problem

The purpose of this study was to investigate the influence of a test-induced stress on the prediction of maximal oxygen intake, as determined by the Astrand-Ryhming nomogram.

Subsidiary Problems

The following subsidiary problems were investigated:

1. The variability of the influence of stress between subjects working at a lower work load, producing a steady state heart rate of approximately 138 beats/min., and those working at a heavier work load, producing a steady state heart rate of approximately 164 beats/min.
2. Determining the inter and intra individual variability of the steady state heart rate values.
3. The influence of anticipation and familiarization of the subjects with repeated testing.

Justification of the Study

It appears evident from the previous discussion that there are a large number of conditions which will alter the submaximal work pulse rate. The influence of stress on predicted maximal oxygen intake is the factor which, at the present time, most requires deeper investigation.

Astrand *et al*. (6) state, on the basis of their research, that the influence of stress may have a marked influence on the heart rate at rest. They go on to state, however, that during exercise the psychological influence on heart rate is more or less abolished.

Until recently, experimenters who employed submaximal tests accepted this assumption that the stress of work overrides the effect of any emotional stress on the work pulse rate (18, 22). A number of authors, at the present time, however, have questioned this assumption and suggested that further investigation is needed into the influence of stress and emotion on submaximal work pulse rates (16, 49, 57, 65, 75).

Taylor *et al*. (65) reported that submaximal pulse rates were significantly higher when subjects took their first test than on retesting. Several other investigators

(29, 49, 57, 60) have reported similar results.

It is necessary at the present time to study the influence of a specific stress situation on a large number of subjects. Rowell, Taylor and Wang (57) studied the effects of the stress of catheterization on seven subjects. They reported no significant difference in pulse rates before training, but a 6 per cent greater underestimation of maximal oxygen intake after training.

Borg and Dahlstrom (20) studied the reliability of pulse rates at submaximal work loads. They found a significantly higher reliability at 900 KPM than at 600 KPM. If this is the case, it would also be significant at the present time to investigate the influence of stress at lower and higher work loads. The work loads selected for this purpose are those which will produce a steady state heart rate of approximately 138 beats/min. or 164 beats/min. If the higher work loads should prove more reliable under the influence of stress, this could perhaps be a partial solution to the problem of the stress factor.

Limitations to the Study

1. Humidity was not controlled. The temperature varied within a ± 2 degree range of 72°F.

2. The experimental errors of the investigator will limit the study.
3. The study is limited by the reliabilities of the methods employed and the limitations of the equipment utilized.
4. The study is limited by the variability of reaction of the individual subject to the test-induced stress.

Delimitations to the Study

1. The study is delimited to 28 girls in second and third year Physical Education at the University of Alberta.
2. Only the parameters in the problem and subsidiary problems are considered.

Definition of Terms

1. Maximal Oxygen Intake: The maximal oxygen intake is the rate of oxygen consumption attained when the cardiorespiratory system can make no further adjustments to increasing work loads, i.e., oxygen intake levels off or declines even if the work load is increased. Mitchell, Sproule, and Chapman (51: 538) state that "...when one subjects a normal individual to progressively increasing work loads, a linear relationship between work load and maximum oxygen intake is found. Ultimately, maximal oxygen intake per unit of time is reached; beyond this point, the work load can usually be increased still

further but, ordinarily, oxygen intake levels off or declines."

2. Steady State: During a steady state, the oxygen intake is equal to the oxygen expenditure. For the purpose of the predicted maximal oxygen intake, Astrand and Ryhming's criterion of two or more consecutive pulse rate readings separated by one minute intervals that do not differ by more than ± 5 beats per minute was used to designate steady state.

3. Maximal and Submaximal Work: Maximal work is the greatest amount of work that a subject is able to perform before exhaustion or fatigue causes termination. Any amount less than this is termed submaximal.

4. Kilopond Meter (KPM): One kilopond meter is the force acting on the mass of one kilogram (Kg) at the normal acceleration of gravity.

5. Work Load: This is the calibrated force of a friction belt which must be overcome by a subject while cycling at a prescribed rate. The work done is a product of the cycling rate, the distance cycled as determined by the wheel circumference, and the belt resistance.

6. Intra-Individual Variance: This is the variance at-

tributable to biological variation in the functional status of the individual.

7. Inter-Individual Variance: This is the variance attributable to true differences between individuals.

8. Maximal Test: A maximal test surpasses the aerobic energy stores of the metabolic system of the body, and causes performance to continue only by anaerobic metabolism, which is an indication of maximal oxygen consumption.

9. Submaximal Test: A submaximal test does not surpass the aerobic limits of the body nor purposely elicit a heart rate exceeding 180 beats per minute.

10. Stress: Stress, according to Bourne (21:95), is defined as "... a specific somatic response to damage or threat of damage by a wide variety of environmental agents, including events having a psychological rather than physical impact." Selye (59:47) goes on to say that it is "...the state which manifests itself by the G.A.S. (general adaptation syndrome). The latter comprises: adrenal stimulation, shrinkage of lymphatic organs, gastrointestinal ulcers, loss of body weight, alterations in the chemical composition of the body, and so forth. All these changes form a syndrome, a set of manifestations which appear together."

CHAPTER II

REVIEW OF THE LITERATURE

Primarily, this review will be concerned with the use of predictive tests of maximal oxygen intake as estimators of physical work capacity, and an examination of the various principles and criteria that pertain to the use of submaximal tests. Specifically, the Astrand-Ryhming nomogram as a valid predictor, and the influence of stress and emotion on the prediction of maximum oxygen intake will be investigated.

The Prediction of Maximal Oxygen Intake from Submaximal Work:

A number of reliable methods for direct measurement of maximal oxygen intake exist but are impractical for testing a large number of subjects in a reasonable length of time. The advantage of a simple work capacity test based on observation during submaximal work has long been recognized (39).

A close linear relationship between pulse rate and oxygen consumption during controlled, stressful submaximal work is reported to exist (5, 31, 53, 65). A number of

investigators (4, 8, 15, 28, 30, 43, 61, 67, 73) have developed submaximal tests, based on this relationship, to predict a subject's maximal oxygen intake. By using extensive empirical analysis of actual relationships, under rigidly standardized conditions (10), close approximations can be made of a subject's aerobic capacity.

The Prediction of Maximal Oxygen Uptake from the Astrand-Ryhming Nomogram:

Astrand and Ryhming constructed a nomogram in 1954, which has been widely used, from which maximal oxygen intake can be predicted from a steady state pulse rate at a known work load (12). Astrand (8) found that when subjects underwent muscular activity of such severity that the demand for oxygen intake was 50 per cent of the individual's maximal oxygen intake, the heart rate after about 6 minutes' work for a group of healthy males averaged 128 beats/min. For female subjects the corresponding heart rate was 138 beats/min. When the subjects worked with a heavier load, thus demanding an oxygen intake of 70 per cent of their aerobic capacity, the average heart rate was 154 for males and 164 for females. The standard deviation was 8-9 beats per minute.

Based on these values, the nomogram was constructed for the prediction of maximal oxygen intake of healthy

individuals between the ages of 18 and 30. With information about the heart rate and oxygen intake during a submaximal work, the subject's aerobic capacity can be estimated. The best results were obtained when the test work was of such a severity that the heart rate during steady state attained a level somewhere between 125 and 170 beats per minute.

Astrand (5) has more recently outlined three prerequisites for the use of the predictive procedure:

1. That the pulse rate during submaximal work increases approximately rectilinearly with the oxygen intake.
2. That submaximal pulse beats not lower than 125 beats per minute are used for the prediction.
3. That the pulse rate of the subject can reach a maximal value of about 195 beats per minute (S.D. ±10) when cycling or walking.

Standard adjustments have been made for age (5), sex (9), apparatus used for exercise (12), and a difference in mechanical efficiency at low work loads (5).

The Accuracy of Prediction from the Nomogram

Astrand and Ryhming (12) established the validity of their nomogram by comparing the calculated and estimated values of oxygen uptake of the subjects studied

(i.e., 27 male and 31 female well-trained subjects, 20-30 years of age). The submaximal test was a cycle test (900 KGM per minute for women, and 1200 for men). A statistical analysis of the values gave a mean difference of 0.023 ± 0.059 (females 0.010 ± 0.051) litres of oxygen per minute between the determined and the calculated maximal oxygen intake. For two-thirds of the cases, the standard deviation was less than 6.7 per cent for men and 9.4 per cent for women. With a lower rate of work, 600 and 900 KGM per minute for women and men respectively, the standard deviations were higher, 14.4 and 10.4 per cent.

A further test of validity was established using 18 well-trained male subjects, 18-19 years of age. The submaximal values were based on step and treadmill tests. The mean difference was 0.006 ± 0.066 litres per minute using the treadmill test for prediction. The standard deviation was less than 7 per cent in each case.

For 31 female and 28 male subjects 20 to 30 years of age, the maximal oxygen uptake was calculated when doing a cycle test (600 and 900 KGM per minute) and a step test. These two values for maximal oxygen uptake were compared, and the mean difference was 0.003 ± 0.052 litres per minute for women and 0.025 ± 0.057 for men. The standard deviations were 9.5 and 7.3 per cent respectively.

In 1960, Astrand (5) reported a standard deviation from the actual measurement of about ± 10 per cent for well-trained individuals and ± 15 per cent for a normal population. The accuracy was somewhat higher when using relatively higher work loads. For 66 males, aged 50 to 59 years, the standard deviation was ± 10 per cent with a correlation coefficient of 0.709 and $P < 0.001$ when the age factor was used. In 1965, Astrand (11) introduced a correction factor for subjects 15 years of age.

Hettinger et al. (39) reported a significant difference between predicted and actual maximal oxygen consumption (2.26 and 2.38 litres per minute) in an experiment using 28 policemen 20 to 30 years of age. This difference was significant at the 5 per cent level of confidence. It was suggested that this difference was possibly due to the fact that the Swedish subjects that Astrand and Ryhming used were well-trained compared to the relatively untrained policemen, and that possibly the measured maximal oxygen uptakes were not attained by the subjects in this study.

To check the reliability of the measured values, nine policemen between the ages of 23 and 48 years were tested (55). The same procedure was used, with the exception that blood lactate levels were used as the criterion indicating maximal uptake. Results indicated

a difference of only 4.8 per cent, with a mean predicted value of 2.65 litres per minute as opposed to a mean measured value of 2.54 litres per minute.

In another group of nine physically well-trained men, ages 56 to 68 years, Astrand et al. (7) reported a mean predicted value of 2.27 litres per minute as compared to the mean measured value of 2.24, a difference of only 3 per cent. In a younger group of untrained men, 23 to 48 years of age, the difference was only about 1 per cent. The respective values for predicted and measured intakes were 2.72 and 2.76 litres per minute (55).

Borg and Dahlstrom (20) investigated the reliability and validity of the nomogram using a bicycle ergometer test with successively increased work levels, for 78, 20 year old men undergoing military training. The highest intra-test correlations were found between the pulse rates from the fourth to the sixth minute at a work load of 900 KPM per minute. On the first test this reliability coefficient value was 0.97, and on the retest, 0.98. The correlation coefficient values for 600 KPM per minute were 0.90 and 0.94 respectively. The correlations at the second and fourth minute were somewhat lower.

The test, retest correlations averaged between 0.50 and 0.60 for 600 KPM level and between 0.60 and 0.70 for

the 900 KPM level. These low correlations may be explained by the fact that the two tests were conducted eight months apart.

The validity of the nomogram was measured against the results of a 20 mile timed ski race, using 42 subjects and conducted between the two experimental tests. The highest correlations (0.38 and 0.45) were obtained between the second work capacity test and the skiing race. The correlation between the Astrand values within the tests were 0.83 and 0.79.

In 1964, de Vries and Klafs (30), using 16 physical education major students 20 to 26 years of age, determined correlations and predictive errors involved in predicting maximal oxygen consumption from six submaximal tests of working capacity. The Astrand-Ryhming nomogram had correlations of 0.736 with a standard error of ± 0.395 litres per minute when compared to the maximal test. When body weight was divided out, the correlation coefficient dropped to 0.522. Of the six tests, the highest predictive values were obtained from the Astrand-Ryhming nomogram and the Sjostrand work capacity test.

Wyndham, _et al_. (74) questionned the validity of the nomogram. They found that it underestimated the maximal oxygen intake by 0.32 ± 0.14 litres per minute. They

stated that this was due to the fact that the pulse rate-oxygen consumption curve deviated towards oxygen consumption at higher pulse rates.

Astrand (5), however, states that it is not the premise of the nomogram to assume that the heart rate is a linear function of oxygen intake throughout the entire range of values. It was not analyzed whether or not the heart rate increased with the oxygen intake at the upper level. Astrand also pointed out that his study was conducted at 5,500 feet above sea level and the effect of prolonged hypoxia might cause discrepancies between actual and predicted values.

Rowell, Taylor and Wang (57) further suggest that, contrary to their conclusions, the nomogram should overestimate the true maximal oxygen intake since they show in their graphs pulse rates at 50 per cent of maximal oxygen consumption as being less than 128 beats per minute.

Rowell, Taylor and Wang (57) also studied the predictability of maximal oxygen intake in normal male subjects 18 to 24 years of age. This study specifically analyzed the influence of physical training on predictability. The predicted test underestimated the value by 27 ± 7 per cent before training and by 11 ± 7 per cent

after training. For a group of ten endurance athletes, the underestimation was 5.6 ± 4 per cent.

Baycroft (16) tested 48 physically active males to evaluate the ability of the Astrand-Ryhming nomogram to predict maximal oxygen consumption. The nomogram correlated significantly ($r = .67$, $p = .01$) with the Mitchell *et al.* test, as well as correlating .62 with the Astrand Bicycle test.

Glassford (36) used an experimental group of 24 healthy, physically active male subjects to compare values on four maximal oxygen consumption tests. The values in litres per minute obtained on the Astrand-Ryhming predicted test correlated 0.80 with the Johnson, Brouha, and Darling test of physical fitness, 0.78 with the Mitchell, Sproule and Chapman test, 0.72 with the Taylor, Buskirk, and Henschel test, and 0.65 with the Astrand actual test. The relationship between the nomogram values and any one set of direct technique values was as good as the relationship between the values of any two direct measures examined in the study.

Hyde (42) investigated the validity of the nomogram for 29 males and 27 females of secondary school age. He reported predicted values equivalent to those obtained on the Astrand actual test for females of secondary school

age, but less accuracy for males of the same age ($p = .01$). The underestimation of the maximal oxygen intake when expressed as a percentage was approximately 10 per cent for male subjects and 5.5 per cent for female subjects when the correction factor for age was used.

The Influence of Stress on Predicted Maximal Oxygen Uptake

Taylor *et al*. (65) gave an excellent review of factors influencing the administration and results of maximal and submaximal tests. As supported by a number of authors (34, 36, 57), factors which influence predicted oxygen uptake include temperature, meals, time of day, fatigue, mechanical efficiency of work, and stress and emotion. These factors generally tend to displace the pulse rate and work rate curve to the left resulting in an underestimation of work capacity.

As mentioned previously, experimenters who employ submaximal work tests appear to make an unstated assumption that the stress of work overrides any effect of emotion on the behavior of the work pulse rate. Brouha and Heath (22), from studies of subjects prior to performance on the Harvard Fitness Test, support this postulation. Bengtsson (18) similarly suggests that mental factors governing emotion would play a rather insignificant role in continuous heavy work.

Master and Oppenheimer (50) and Sjostrand (61) question whether mental factors would have any significant effect on submaximal work. Astrand _et al_. (6) suggest, on the basis of their investigations, that apprehension may have a marked influence on the heart rate and respiratory rate of a subject during rest, but during exercise, the psychic influence on heart rate and respiration is more or less abolished.

Direct evidence on the influence of emotion and stress on submaximal pulse rates is generally lacking in the literature, however, the article by Taylor _et al_. (65) has thrown more light on this question. They have reported that the initial contact with a work test can result in significant increases in submaximal work pulse rates. This was based on a study of 7 athletes and 6 non-athletes performing a preliminary warm-up by walking on the treadmill at a 10 per cent grade for 15 minutes. The deviations were more marked in the case of the athletes.

Rowell, Taylor and Wang (57), employing predictions from the nomogram, have stated that the differences between the first and second predicted values for maximal oxygen intake for 20 trained and untrained subjects were significant at the level of $P = 0.02$. They also suggested that, very frequently, particularly in physically trained subjects, repeated determinations of submaximal pulse rates

are necessary before the rates stabilize and become reproducible at a given work intensity.

Zahar (75) used 38 male high school students to investigate the influence of repeated administration of the Sjostrand test. He has stated that a feeling of apprehension decreased the value of the first test of work capacity.

In 1966, Shephard (60) studied the relative merits of the step test, bicycle ergometer, and treadmill in the assessment of cardio-respiratory fitness for 10 sedentary males. He found that frequency of experimentation led to some decrease in the pulse rate at a given submaximal oxygen consumption equivalent to a 1.6 per cent increase of predicted aerobic work capacity from session 2 to session 4, and an 8 per cent increase from session 3 to 24. Since there was no gain in the directly measured maximal oxygen uptake from session 7 to 25, he has stated that these differences may reflect habituation more than true training.

Day (29) studied the reliability of the Ryhming Step Test for the prediction of aerobic capacity using 58 male subjects who were tested twice with a one week interval between tests. He reported a significant improvement in performance in the second test which he sug-

gested was due to familiarization with the test. Hyde (42) has reported similar results.

Macnab and Conger (49) tested 80 university women on three occasions using the nomogram for prediction. They found that improvement occurred with each administration of the test for athletes and non-athletes. The successive predicted means were 2.21, 2.33 and 2.41 litres respectively. They have also suggested that the probable effect of anxiety is reflected by the heart rates prior to, during, and at the end of exercise, and that emotional stress may not be overridden by exercise stress.

Taylor et al. (65) have reported definite deviations from normal pulse rates for one subject during a low submaximal walk on the treadmill (3.5 miles per hour on a 10 per cent grade for 6, 10 minute periods) due to the sudden shock of falling. The work pulse rate rose from 130 beats per minute to almost 160 beats per minute, and his pulse rate did not become lower on successive trials until the fifth repetition.

Rowell, Taylor and Wang (57) also investigated the effects of the stress of indwelling peripheral and central vascular catheters on 7 subjects, before and after training. Before training, there were no significant differences. However, following training, there was a 6 per cent greater

(P = 0.001) underestimation with prediction from the nomogram under the added stress of catheterization. The observed maximal value was unchanged. Similar effects were reported with six endurance athletes.

Taylor *et al*. (65) and Baycroft (16) have pointed out that, in many cases, the data reported on the influence of stress and emotion on the prediction of maximal oxygen intake has been a result of intermittent work. They, and a number of other investigators (38, 42, 75), have suggested that much more study is required before any conclusions can be made.

CHAPTER III

METHODS AND PROCEDURES

Twenty-eight healthy female subjects were used in this study with the total being comprised of volunteer students in second and third year Physical Education at the University of Alberta, Edmonton. The ages of the subjects ranged from 18 to 25 with a mean age of 20.

The tests were conducted over a period of three to four weeks for each subject with a minimum of two and a maximum of five days between separate tests. The experiment began March 3, 1971, and was completed March 31, 1971. The data was collected Monday through Thursday inclusive of each week.

Physical Conditions of the Testing Situation

As mentioned in the previous chapter, temperature may affect maximal oxygen intake (25, 34, 57, 71) and heart rate (33, 61). In this study, the laboratory temperature was standardized at 72 ± 2 degrees F., but the relative humidity was not controlled.

Standardization of the Test Situation

Because the ingestion of food has a known effect

on pulse rate and cardiac output (48, 64), no test was scheduled for a period of one and a half hours following a meal. Subjects were requested not to smoke for an hour prior to the test and not to perform any strenuous activities for one and a half hours before their test. In all instances, the test schedules for each individual were arranged so that the subject was tested at the same relative time of the day.

Orientation Period

Every subject was brought to the laboratory five days prior to the commencement of the actual test for the purpose of orientation. At this time, height, age, weight, and smoking habits were recorded. The testing procedure was carefully explained and each subject was given the opportunity to practice the test on the bicycle ergometer. Subjects were told that the experiment was designed to test the reliability of the Astrand-Ryhming Nomogram, but were given no indication that there would be a test-induced stress involved. Each subject was then assigned her testing schedule.

Predicted Test Apparatus

The following apparatus was used for the Astrand sub-maximal test:

(1) a Monark Bicycle Ergometer; (2) a metronome (mechanical); (3) a stop watch calibrated to 1/10 of a second; (4) a Sanborn 100 Viso-Electrocardiograph; (5) a Continental Scale (Model #400 DFK); and (6) a starting pistol (R.G. 7 ROHM).

The Astrand-Ryhming Predicted Maximal Oxygen Intake Test

The test was conducted on a Monark Bicycle Ergometer, designed by von Dobeln (66), which works on the principle of a weighing device called the sinus balance. The testing procedure closely followed the description given by Astrand (11).

The height of the saddle was adjusted so that when the subject had the front part of the sole of her foot level on the pedal, a slight bend of the knee joint resulted in the extended leg (i.e., the front part of the knee was straight above the tip of the toes). The handlebars were adjusted to the subject's liking. A pre-exercise heart rate was then recorded.

The metronome was set at 100 beats per minute so that the subject would pedal at 50 revolutions per minute. The sinus balance was carefully zeroed before the commencement of the test.

When the work was started, the brake belt was

slack and was quickly adjusted to the desired work level by stretching the belt with the aid of the handwheel designed for this purpose. This adjustment could be made in a few seconds, but as the wheel and belt warmed up, the friction sometimes changed, necessitating the occasional readjustment. A check of the load was made at least once a minute.

For all subjects in this study, the work level was initially set at 600 KPM. Heart rate recordings were made on a Sanborn electrocardiagram during the last fifteen seconds of every minute. The subject pedalled at this work level for 6 minutes until a steady state was attained (two consecutive heart rate recordings separated by one minute which differ no more than ±5 beats). If, after six minutes, this steady state was not in the range of 125 to 170 beats per minute, the work load was increased to 900 KPM and the subject continued to ride for 3 minutes until a steady pulse rate was reached. The steady state pulse rate value was then applied to the Astrand-Ryhming nomogram (12) in relation to the work load and a maximal oxygen uptake value was estimated.

The subjects were randomly placed into two groups after their initial test. Group I was the low work load group and Group II was the higher work load group. For

the subjects in Group I, based on their steady state heart rate response to the initial test at 600 KPM, a work load was estimated which would produce a steady state heart rate of approximately 138 beats/min. For Group II, a work load was estimated so that a steady state of approximately 164 beats/min. was produced. A full description of this estimation procedure is listed in the appendix. This same work load was used for trials 1 through 4.

These two criteria levels for low and high work loads were selected on the basis of the results of Astrand and Ryhming (12). They reported that, after 6 minutes of exercise, the average heart rate for 16 healthy female subjects was 138 beats/min., when exercising at 50% of their maximal oxygen intake. At heavier work loads, demanding 70% of their aerobic capacity, the average heart rate was 164 beats/min.

Test number one was the control trial. The second test was the test-induced stress trial, and tests three and four were used to investigate any possible carry-over effect from the stress in test number two.

Method of Inducing Stress

The test-induced stress was administered during the first five seconds of the second testing session. The

starting pistol was fired once into the air directly behind the subject's head (within 6 to 8 inches). She received no warning prior to the firing that such a stress would be administered. The pistol shot was not used in tests numbers three and four. However, subjects received no indication previous to these tests as to whether or not the pistol would be fired.

Pulse Rate Recordings

Heart rate recordings were made by means of a Sanborn portable electrocardiagram, the leads of which were attached to two chest and two upper back electrodes. Careful attention was given to preparation of the electrodes with Redux (tradename) electrode paste.

Calibration of Instruments

The sinus balance was calibrated by means of a set of stainless steel weights, #750 class S-1 Serial No. 7Y1458 in the following manner (11):

a) The brake drum was removed and the mark on the pendulum weight was set at "0."

b) A one kilogram weight was attached to the spring. Weights were added or taken from the spring as required to bring the mark on the pendulum to the required scale mark of "1-KP."

c) The process was continued through "2-KP," "3-KP"

and so on up to "7-KP."

d) If adjustment was required it was made by means of an adjusting screw which altered the centre of gravity of the sinus balance.

The bob on the pendulum was then changed from stainless steel weighing 817 grams to aluminum weighing 168 grams. The procedure described above was repeated for the lighter pendulum so that lighter work loads and finer work load gradations could be produced.

Statistical Treatment

Pearson Product-Moment correlation coefficients between the mean steady state heart rates over the four trials were determined for all 28 subjects and for both groups by means of an IBM-1620 Electronic computer program (DEST 02), at the University of Alberta Computer Center, which also provided a mean and standard deviation for each variable. This program was also used to compute means and standard deviations for the mean pre-exercise heart rates over the four trials for all 28 subjects and for both groups.

The significance of the difference between means obtained on the four trials of predicted maximal oxygen

uptake for Group I (low work load) and Group II (high work load) was tested with a two way analysis of variance technique repeated on four trials (72:302). A one way analysis of variance repeated on four trials (72:105) was used to determine any differences between the treatment means for Group I and Group II.

CHAPTER IV

RESULTS AND DISCUSSION

Results

Means, Standard Deviations and Range Values for Age, Height and Weight

Table I gives the means, standard deviations and range values for the 28 subjects used in the study. Table II gives these values for the 14 subjects in Group I and the 14 subjects in Group II.

TABLE I

MEANS, STANDARD DEVIATIONS AND RANGE VALUES FOR AGE, HEIGHT AND WEIGHT FOR ALL 28 SUBJECTS

Parameter	Mean	Standard Deviation	Range
Age (Years)	20.18	1.51	18-25
Height (inches)	64.53	2.86	60-69
Weight (pounds)	133.57	18.61	105-178

TABLE II

MEANS, STANDARD DEVIATIONS AND RANGE VALUES FOR AGE, HEIGHT AND WEIGHT FOR SUBJECTS IN GROUP I AND SUBJECTS IN GROUP II

Parameter	Mean	Standard Deviation	Range
Group I (N=14)			
Age (years)	20.29	1.38	19-24
Height (inches)	63.68	2.51	605-69
Weight (pounds)	129.64	20.85	107-178
Group II (N=14)			
Age	20.07	1.64	18-25
Height	65.38	3.10	60-69
Weight	137.50	16.36	105-173

Means for Steady State Heart Rates and Predicted Maximal Oxygen Uptake Values for Subjects During the Initial Trial (at 600 KPM)

Table III gives the means for the steady state heart rates and predicted maximal oxygen uptake values for the initial trial at 600 KPM. It also gives these values for the subjects in Group I and for the subjects in Group II.

TABLE III

MEANS FOR STEADY STATE HEART RATES AND PREDICTED MAXIMAL OXYGEN UPTAKE VALUES FOR SUBJECTS DURING THE INITIAL TRIAL (at 600 KPM)

Statistic	All Subjects (N=28)	Group I (N=14)	Group II (N=14)
Mean Steady State Heart Rate (beats/min)	150.79	151.18	150.39
Mean Predicted Max. O_2 Uptake (litres/min)	2.49	2.46	2.51

Means, Variances and Standard Deviations for Steady State Heart Rates for the Four Trials

Table IV gives the means, variances and standard deviations for all 28 subjects of the steady state heart rates used for the prediction of maximal oxygen intake for each of the four trials. Table V gives these same values for all subjects in Group I and all subjects in Group II.

TABLE IV

MEANS, VARIANCES AND STANDARD DEVIATIONS FOR STEADY STATE HEART RATES FOR THE FOUR TRIALS FOR ALL 28 SUBJECTS EXPRESSED IN BEATS/MIN.

Statistic	Trial 1	Trial 2 (Stress)	Trial 3	Trial 4
Mean	149.73	151.07	147.29	145.38
Variance	281.23	293.78	204.49	200.79
Standard Deviation	16.77	17.14	14.30	14.17

TABLE V

MEANS, VARIANCES AND STANDARD DEVIATIONS FOR STEADY STATE HEART RATES FOR THE FOUR TRIALS FOR GROUP I AND GROUP II EXPRESSED IN BEATS/MIN.

Statistic	Trial 1	Trial 2 (Stress)	Trial 3	Trial 4
Group I (N=14)				
Mean	134.14	136.86	135.54	133.07
Variance	58.58	86.68	86.12	70.06
Standard Deviation	7.66	9.31	9.28	8.37
Group II (N=14)				
Mean	165.32	165.29	159.04	157.69
Variance	23.81	111.09	56.85	36.60
Standard Deviation	4.88	10.54	7.54	6.05

From Table IV it was noted that there was a slight increase in the mean steady state heart rate for all 28 subjects in trial 2 (the stress trial) and then a slight decrease in trials 3 and 4. Similar results were observed in Table V for Group I.

For Group II it was noted that there was a general decrease in the mean steady-state heart rate over the four trials, the greatest decrease occurring in trials 3 and 4. These mean steady state heart rates are plotted in Figure

1.

It should also be noted that trial 2 had the greatest variance of the four trials for the whole group (N=28) and for each group separately (N=14). This was particularly marked for Group II.

Means of the Predicted Maximal Oxygen Intake Values for the Four Trials

Table VI gives the means for the predicted values of maximal oxygen intake over the four trials for the whole group and then for Group I and for Group II.

TABLE VI

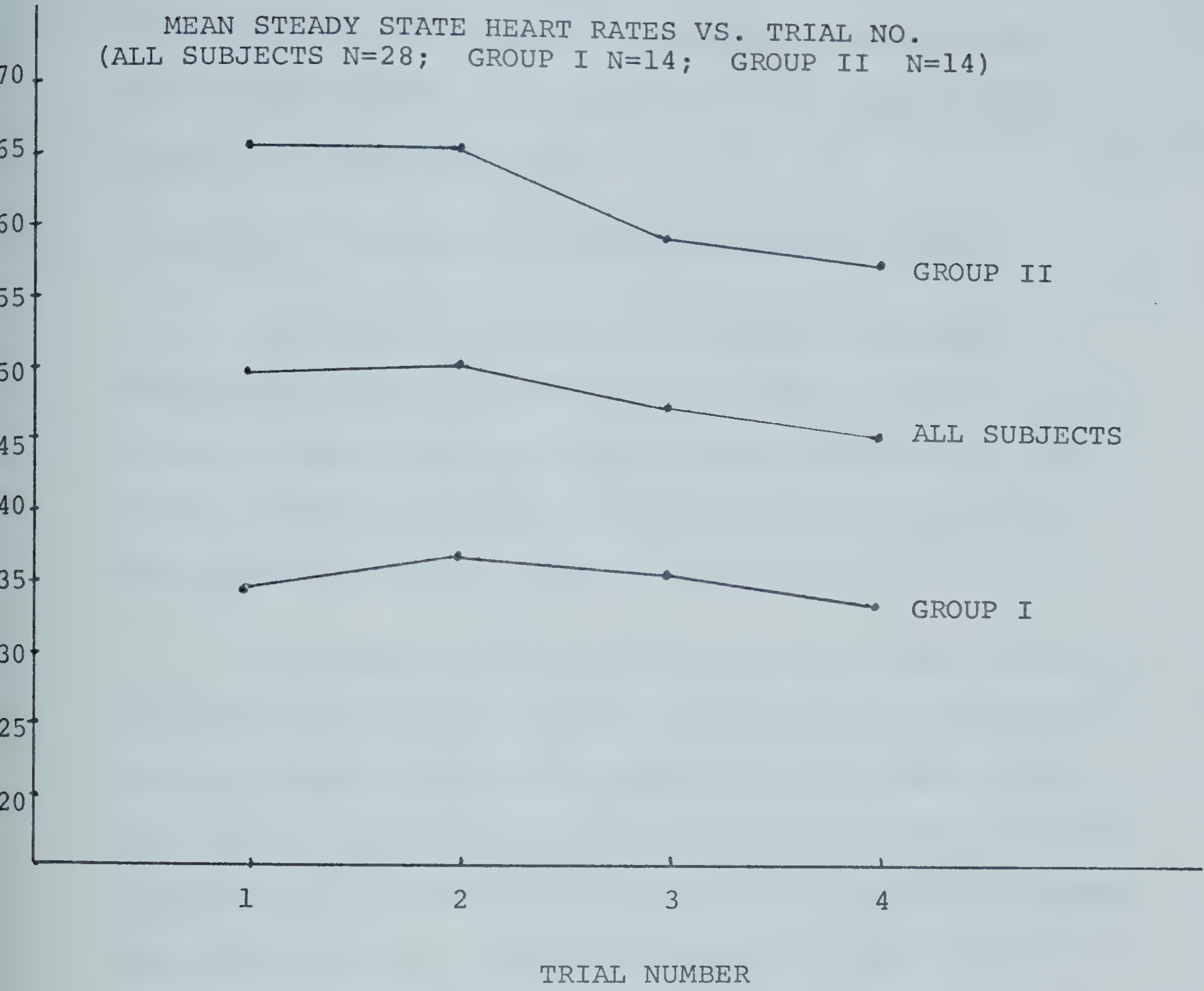
MEANS OF THE PREDICTED MAXIMAL OXYGEN INTAKE VALUES FOR THE FOUR TRIALS EXPRESSED IN LITRES/MIN.

Group	Trial 1	Trial 2	Trial 3	Trial 4
All Subjects (N=28)	2.58	2.53	2.63	2.72
Group I (N=14)	2.69	2.57	2.61	2.74
Group II (N=14)	2.46	2.49	2.65	2.69

Similarly, for the mean predicted values, for all 28 subjects, it was noted that there was a slight decrease in predicted maximal oxygen intake in trial 2, and a general improvement in trials 3 and 4. Similar results

FIGURE I

MEAN STEADY STATE HEART RATES VS. TRIAL NO.
(ALL SUBJECTS N=28; GROUP I N=14; GROUP II N=14)



were observed for Group I. For Group II, there was a general improvement over the four trials, the greatest occurring in trials 3 and 4.

Analysis of Variance of Steady State Heart Rates

In order to test for significant difference between the means for both groups together over the four trials, a two way analysis of variance repeated on four trials (72:302) was used. A summary of the results of the variance analysis appears in Table VII.

The means for both groups, over the four trials, expressed in beats per minute were shown to be statistically different at the .01 level of significance, using the F ratio test. This result held true for the 'A' main effects (i.e., there was a significant difference between means for the two groups which would be expected due to the experimental design) and for the 'B' main effects (i.e., there was a significant difference between the means over the four trials).

Due to this significant difference between means over the four trials, it was thus necessary to determine specifically wherein this significance lay. For this purpose, a one way analysis of variance repeated on four trials (72:105) was used first for Group I and then for Group II. A summary of the results of the variance ana-

lysis for each group appears in Table VIII.

The results indicated that for Group I (i.e., low work load), there was no significant difference (p = .01) between the mean steady state heart rates over the four trials. For Group II (i.e., high work load), however, a significant difference (p = .01) between the four means did exist. It appears that this difference is not between trials 1 (control trial) and 2 (stress trial). The mean steady state heart rates for these trials were 165.32 beats per minute and 165.29 beats per minute, respectively. It appears that this difference exists, however, between the following trials: 1 and 3 (i.e., 165.32 and 159.04), 1 and 4 (i.e., 165.32 and 159.04), 2 and 3 (i.e., 165.29 and 159.04), and 2 and 4 (i.e., 165.29 and 157.20).

TABLE VII

TWO WAY ANALYSIS OF VARIANCE REPEATED ON FOUR TRIALS (FOR GROUPS I AND II COLLECTIVELY) OF STEADY STATE HEART RATES (beats per minute)

Source of Variation	Sum of Squares	df	Mean Square	F
Between Subjects	25069.00	27		
'A' Main Effects	20304.38	1	20304.38	110.79**
Subjects within groups	4765.00	26	183.27	

TABLE VII, continued

Source of Variation	Sum of Squares	df	Mean Square	F
Within Subjects	2926.00	84		
'B' Main Effects	540.75	3	180.25	6.62**
'A x B' Interaction	262.50	3	87.50	3.21*
'B' x Subjects Within Groups	2124.00	78	27.23	

** Statistically significant at the .01 level.

* Statistically significant at the .05 level.

TABLE VIII

ONE WAY ANALYSIS OF VARIANCE REPEATED ON FOUR TRIALS (FOR GROUPS I AND II SEPARATELY) OF STEADY STATE HEART RATES (beats per minute)

GROUP I:

Source of Variation	Sum of Squares	df	Mean Square	F
Between People	2668.88	13	205.298	
Within People	1363.50	42	32.46	
Treatments	114.25	3	38.08	1.19
Residual	1249.25	39	32.03	
Total	4032.38	55		

GROUP II:

Source of Variation	Sum of Squares	df	Mean Square	F
Between People	2096.00	13	161.23	

TABLE VIII, continued

Source of Variation	Sum of Squares	df	Mean Square	F
Within People	1562.00	42	37.19	
Treatments	688.00	3	229.33	10.23**
Residual	874.00	39	22.41	
Total	3658.00	55		

**Statistically significant at the .01 level of significance.

Inter-trial Correlation Coefficients for Steady State Heart Rates

The correlation coefficients reported were obtained using the IBM computer program for Pearson Product-Moment correlations. Table IX summarizes the correlation coefficients for steady state heart rates obtained over the four trials for all the subjects, Table X for Group I, and Table XI for Group II.

TABLE IX

PEARSON PRODUCT-MOMENT CORRELATION COEFFICIENTS FOR STEADY STATE HEART RATES BETWEEN THE FOUR TRIALS FOR ALL 28 SUBJECTS

	Trial Number		
Trial Number	2	3	4
1	0.89**	0.89**	0.90**
2		0.88**	0.89**
3			0.92**

**Statistically significant at the .01 level

Of the correlation coefficients reported for all 28 subjects, all were found to be statistically significant at the .01 level. The highest correlation (0.92) was observed between trials 3 and 4, and the lowest correlation (0.88) was observed between trials 2 and 3.

TABLE X

PEARSON PRODUCT-MOMENT CORRELATION COEFFICIENTS FOR STEADY STATE HEART RATES BETWEEN THE FOUR TRIALS FOR GROUP I (N=14)

	Trial Number		
Trial Number	2	3	4
1	0.39	0.51	0.50
2		0.47	0.61*
3			0.73**

**Statistically significant at the .01 level
*Statistically significant at the .05 level.

TABLE XI

PEARSON PRODUCT-MOMENT CORRELATION COEFFICIENTS FOR STEADY STATE HEART RATES BETWEEN THE FOUR TRIALS FOR GROUP II (N=14)

	Trial Number		
Trial Number	2	3	4
1	0.78**	0.61*	0.42
2		0.70**	0.57
3			0.58*

**Statistically significant at the .01 level.
*Statistically significant at the .05 level.

Of the correlation coefficients reported for Group I only the correlations between trials 4 and 2 (0.61, which was significant at the .05 level), and trials 4 and 3 (0.73, which was significant at the .01 level) were found to be statistically significant.

Of the correlations reported for Group II all were found significant except those between trials 4 and 1 (0.42) and trials 4 and 2 (0.57). Trial 2 correlated 0.78 ($p = .01$) with trial 1, trial 3 correlated 0.61 ($p = .05$) with trial 1, trial 3 correlated .70 ($p = .01$) with trial 2, and trial 4 correlated 0.58 ($p = .05$) with trial 3.

Means, Variances and Standard Deviations for Pre-Exercise Heart Rates

Pre-exercise heart rates were recorded for each subject approximately one minute prior to the start of each trial. Table XII gives the means, variances and standard deviations for all 28 subjects of the pre-exercise heart rates recorded for each of the four trials. Table XIII gives these same values for the 14 subjects in Group I and for the 14 subjects in Group II.

TABLE XII

MEANS, VARIANCES AND STANDARD DEVIATIONS FOR PRE-EXERCISE HEART RATES FOR THE FOUR TRIALS FOR ALL 28 SUBJECTS (beats/min)

Statistic	Trial 1	Trial 2	Trial 3	Trial 4
Mean	76.64	79.50	73.22	70.11
Variance	361.76	235.59	112.72	176.98
Standard Deviation	19.02	15.33	10.29	13.24

TABLE XIII

MEANS, VARIANCES AND STANDARD DEVIATIONS FOR PRE-EXERCISE HEART RATES FOR THE FOUR TRIALS FOR GROUP I (N=14) AND GROUP II (N=14) (beats/min)

Statistic	Trial 1	Trial 2	Trial 3	Trial 4
Group I				
Mean	72.64	73.71	74.64	68.86
Variance	364.43	212.29	166.93	142.56
Standard Deviation	19.09	14.57	12.92	11.94
Group II				
Mean	80.64	85.29	71.79	71.36
Variance	359.10	258.89	58.52	211.41
Standard Deviation	18.95	16.09	7.65	14.54

It was noted from Table XII that there was a slight increase in mean pre-exercise heart rate in trial 2 and a marked decrease in trials 3 and 4 for all 28 subjects.

The results in Table XIII indicated a slight increase for these values for trials 1 to 3 in the case of Group I, with a marked decrease for trial 4. For Group II, there was an increase in the mean pre-exercise heart rate from trial 1 to 2, but a very marked decrease in trials 3 and 4. Mean pre-exercise heart-rates for the four trials are plotted in Figure II.

The results in Tables XII and XIII also indicated the greatest variance occurred in trial 1.

Mean Pre-Exercise and During Exercise Heart Rates of Group I and II for the Four Trials

Table XIV gives the mean pre-exercise heart rates and the mean heart rates at the end of each minute of exercise (minutes 1 to 6) for trials 1 to 4. The mean heart rates at the end of the first 30 seconds of exercise for trials 2 and 3 are also included for both groups.

These means heart rates for each trial are plotted in Figure III. It should be noted for both groups that the mean heart rates at the end of 30 seconds and 1 minute for trial 2 (i.e., the stress trial) are slightly higher

FIGURE II

MEAN PRE-EXERCISE HEART RATES VS. TRIAL NO.
(ALL SUBJECTS N=28; GROUP I N=14; GROUP II N=14)

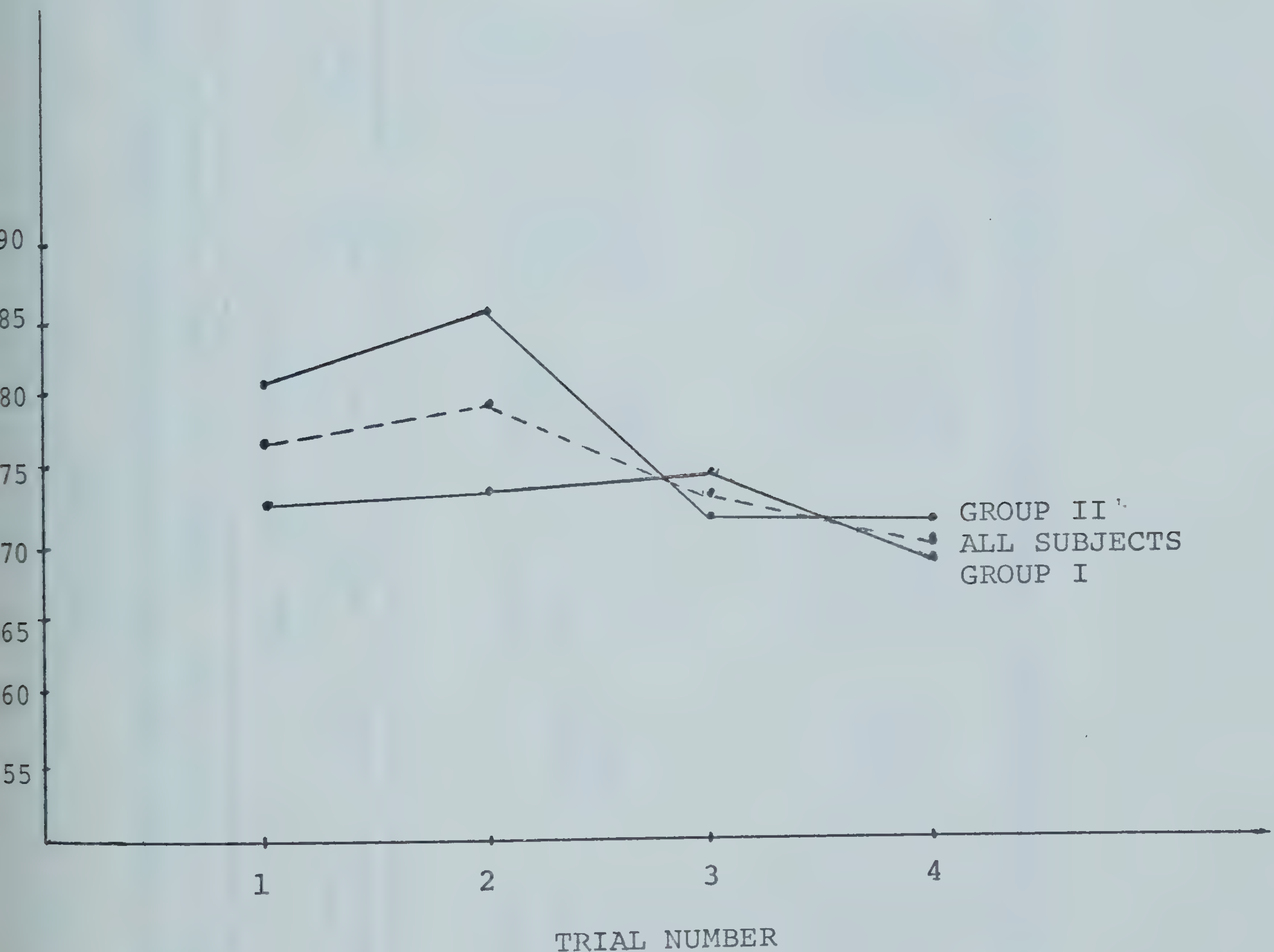


TABLE XIV

MEAN HEART RATES BEFORE AND DURING EXERCISE FOR FOUR TRIALS FOR GROUPS I AND II (beats/min) (STRESS at 5 sec. in Trial 2)

Trial Number	Mean Heart Rates at							
	Pre-Exercise	30 secs	1 min.	2 min.	3 min.	4 min.	5 min.	6 min.
Group I (N=14)								
1	72.64		121.07	126.64	130.14	132.07	133.21	134.78
2	73.71	111.53	123.71	129.78	132.64	132.64	135.71	138.00
3	74.64	109.23	121.57	126.78	127.21	131.42	135.57	135.50
4	68.86		119.85	125.00	128.35	130.28	132.00	134.00
Group II (N=14)								
1	80.64		142.07	153.14	158.64	161.85	164.85	165.92
2	85.29	126.63	145.35	151.85	157.35	160.92	165.00	165.57
3	71.79	123.58	140.07	148.00	151.00	155.85	158.35	159.71
4	71.36		137.21	146.78	148.71	152.00	155.07	158.78

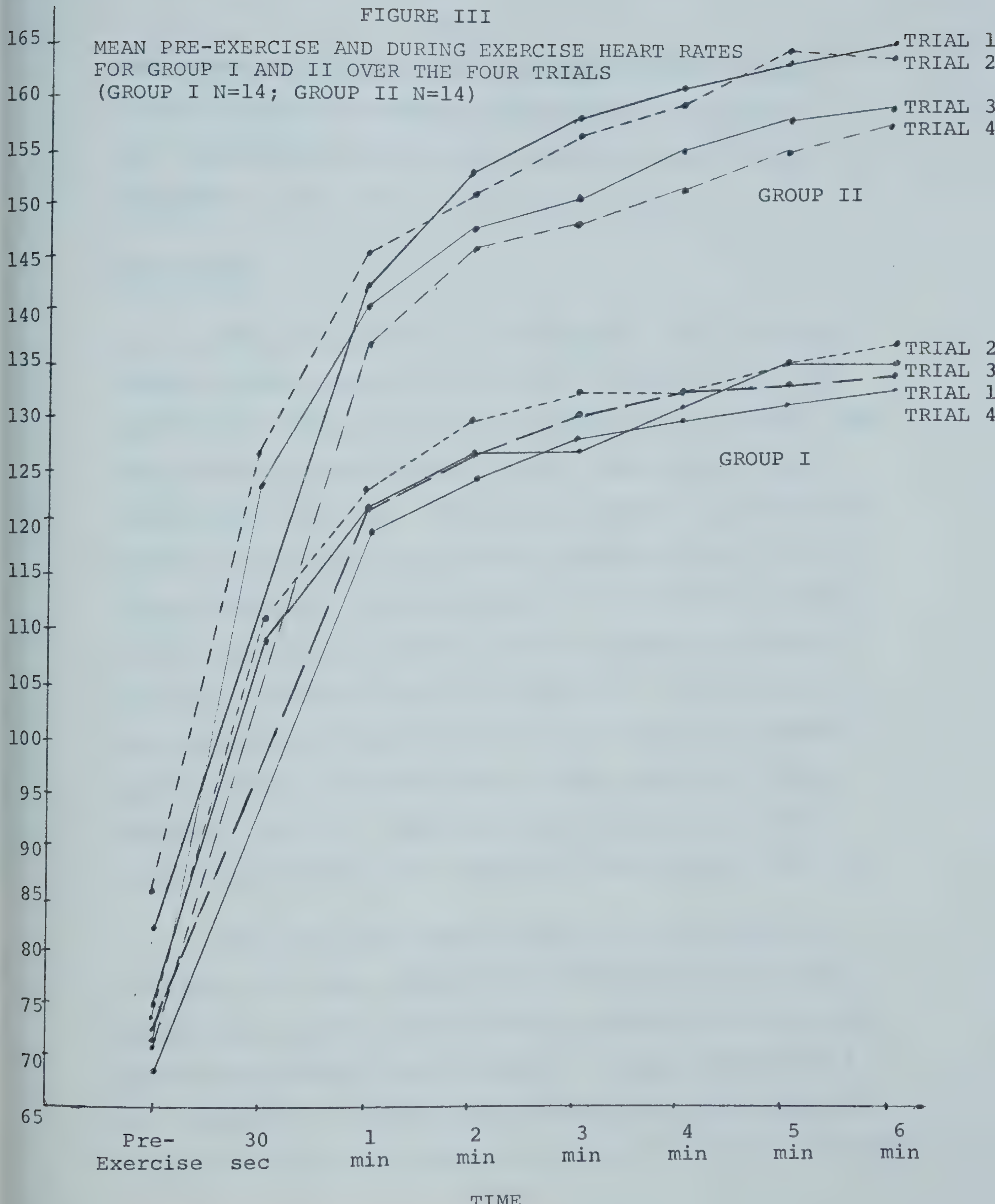


FIGURE III
MEAN PRE-EXERCISE AND DURING EXERCISE HEART RATES
FOR GROUP I AND II OVER THE FOUR TRIALS
(GROUP I N=14; GROUP II N=14)
TRIAL 1
TRIAL 2
TRIAL 3
TRIAL 4
GROUP II
TRIAL 2
TRIAL 3
TRIAL 1
TRIAL 4
GROUP I
165
160
155
150
145
140
135
130
125
120
115
110
105
100
95
90
85
80
75
70
65
Pre-
Exercise
30
sec
1
min
2
min
3
min
4
min
5
min
6
min
TIME

than those reported in the other three trials. This slight elevation for Group I disappears at the end of the fourth minute of exercise, while for Group II it disappears at the end of the second minute.

Discussion

The practicality of a submaximal test to predict maximal oxygen uptake has long been recognized and the validity of this type of test compared to tests which measure maximal oxygen uptake directly has also been well established (16, 36). There are a number of conditions, however, which may influence the results of such an indirect technique. The influence of environmental stress on the prediction of maximal oxygen uptake is a factor which has received little investigation. Originally, it was assumed that the influence of any such environmental psychological stress was more or less abolished during exercise (18, 22). However, this assumption has been recently questioned by a number of investigators (64, 75).

The experiment was designed to investigate the influence of a test induced environmental stress on the reliability of the Astrand-Ryhming Nomogram technique for predicting maximal oxygen uptake. It also investigated any variation of results which might occur under the influence of stress for subjects working at a lower work load,

producing a steady state heart rate of approximately 138 beats/min., and those working at a heavier work load, producing a steady state heart rate of approximately 164 beats/min.

The mean values obtained from the tests, executed in this study, generally agree with those reported in the literature for the age group and sex concerned. Astrand (8) reported a value of 2.92 ± 0.27 litres of oxygen per minute for 29 female well-trained subjects 20 to 30 years of age, cycling at 900 kgm/min. These results should be expected to be slightly greater in value since they were obtained from a group of well-trained females. Macnab and Conger (49) reported values of 2.53 to 2.79 for 40 females aged 17 to 23, who were participants on intercollegiate athletic teams, working at 450 KPM. For 40 non participant volunteers, the results ranged from 1.89 to 2.01 over three trials. These lower values, in the case of the non participants, was probably the result of a lesser degree of cardiovascular fitness of the subjects.

As may be seen from the successive means for all 28 subjects in Table IV and Figure I, there was a slight increase in the mean steady state heart rate for trial 2, and then a slight decrease in trial 3 and trial 4. There was also a slight increase in the variance of results for trial 2.

Similar results were observed for Group I (the low work load group), as shown in Table V.

For Group II (the high work load group), there was a general decrease in the mean steady state heart rates over the four trials, the greatest decrease occurring between trial 2 and trial 3. Again, the variance in trial 2 was slightly higher than in the other trials.

Zahar (75) suggests that this general improvement with repeated testing may be due to a training effect, resulting in increased cardiorespiratory efficiency through practice. Krogh and Lindhard (46) suggested that learning may take place in areas where bicycle riding is not too popular. Astrand (10), however, states that learning on the bicycle ergometer is negligible.

Shephard (60) and Zahar (75) suggest the increase in predicted maximal oxygen intake with repetition of the test may reflect habituation and that a feeling of apprehension may decrease the value of the first test. In this connection, the probable effect of anxiety, as reflected by the pre-exercise heart rates, listed in Tables XII and XIII, should particularly be noted. The mean pre-exercise heart rates for trials 1 and 2 were higher than trials 3 and 4. As mentioned previously, the mean steady state heart rates for trials 3 and 4 were similarly lower. These

results tend to support the contention that anxiety, as reflected by the pre-exercise heart rates, may decrease the value of the first trials.

A significant difference between the means for both groups over the four trials (P = .01) was indicated by a two way analysis of variance repeated on four trials (72: 302), as shown in Table VII. A one way analysis of variance repeated on four trials (72:105) for Group I indicated no significant difference (P = .05) between the mean steady state heart rates, but did indicate a significant difference for Group II. As noted previously, however, this difference did not appear to exist between trials 1 (control trial) and 2 (stress trial), but rather with trials 3 and 4. These results indicate that the test induced stress administered in trial 2 had no significant influence on the prediction of maximal oxygen intake for either the low or high work load group.

In an attempt to illustrate any influence that the test-induced stress may have had, the mean heart rates obtained on all four trials for both groups were plotted at the beginning of the test, the end of 30 seconds, the end of 1, 2, 3, 4, 5, and 6 minutes of exercise, as shown in Figure III. A slight increase in the mean heart rates for both groups at the end of 30 seconds and 1 minute can

be observed in trial 2. These results suggest that the experimental stress did influence the mean heart rates during exercise, but this influence had disappeared by the end of the fourth minute of exercise for Group I and by the end of the second minute of exercise for Group II. These results would tend to support the assumption of Astrand et al. (6) that during exercise the psychic influence of environmental stress on heart rate and respiration is more or less abolished. They also tend to support Borg and Dahlstrom's (20) contention that the reliability of the nomogram was higher with heavier work loads. However, the above data were not treated statistically, and the increase in mean heart rate from pre-exercise to 30 seconds was only slightly higher in trial 2 than trial 3 for Group I, and actually lower for Group II.

It was mentioned, previously, that a decrease in the mean steady state heart rates over the four trials did occur, suggesting that habituation of the subjects with repetition of the test did affect the results. It should be noted, however, that this decrease in mean steady state heart rates over the four trials was not as great as that reported by Macnab and Conger (49). They reported a decrease of 5.5 beats/min. between trials 1 and 3. The results of this study, however, as shown in Table IV, indicate a decrease of only 2.4 beats/min. between trials

1 and 3, and 4.4 beats/min. between trials 1 and 4. It may, thus, be suggested that stress may have had some influence even though it did not produce a signficant difference.

It is possible that had the test induced stress been administered nearer the end of exercise rather than at the very beginning, there might have been an influence on the steady state values. It is further conceivable that had the test induced stress been of greater severity, the influence on heart rate may have been more marked and prolonged until the end of the exercise period. Taylor et al. (65) reported that the intense stress produced by a fear of falling on the treadmill produced deviations in the steady state pulse rate of one subject for several days and did not disappear until the fifth successive repetition.

In addition, the subjects used in this study were physical education students in 2nd and 3rd year university. It is suggested that subjects would be in better physical condition than non participants. However, they cannot be classified as highly trained individuals. Rowell, Taylor and Wang (57) reported that the stress of catheterization resulted in a 6 per cent greater underestimation of maximal oxygen uptake with prediction from the nomogram for trained subjects, but no significant differences prior to training.

Correlation coefficients between the mean steady state heart rate results over the four trials, for all 28 subjects are shown in Table IX. These results were all found to be statistically significant at the .01 level of significance and almost equivalent in value. The correlation coefficient between trials 3 and 4 was slightly higher (0.92) further suggesting habituation of the subjects with repeated testing. The correlation coefficient between trials 2 and 3 (0.88) was slightly lower suggesting perhaps a slight influence from the stress factor in trial 2 and some anticipation effect in trial 3.

Correlation coefficients between the results on the four trials for Group I are shown in Table X. Based on a group of 14 subjects, and a non significant F between the mean steady state heart rates over the four trials, there was a low correlation between trial 1 (control) and trial 2 (stress trial) (0.39), a low correlation between trial 2 and trial 3 (control) (0.47), and low correlations between trial 1 and trial 3 (0.51), and trial 1 and trial 4 (0.50).

One would expect a low correlation in these first two results due to the test-induced stress in trial 2. A higher correlation, however, would be expected between trial 1 and trials 3 and 4. These low correlations may be

partially explained by the time factor between these trials, by the small size of the group, by habituation of the subjects by the third and fourth trials, and because of the actual design of the study (i.e., individual workloads were estimated so that subjects reached a steady state heart rate of approximately 138 beats/min.).

It can also be seen that trial 2 and trial 4 showed a higher correlation (0.61). This result and the low correlation between trial 2 and trial 3 may be perhaps explained by an anticipation effect in trial 3 resulting from the test induced stress in trial 2. The highest correlation (0.73) is between trials 3 and 4 which may be explained by habituation of the subjects with repetition of the test.

Correlation coefficients for the mean steady state heart rates for Group II over the four trials are listed in Table X. Again, based on a group of 14 subjects, but a significant F between the mean values, it can be seen that the correlation coefficients between trial 1 and trial 4 (0.42) and trial 2 and trial 4 (0.57) were not significantly greater than 0. These low correlations may be partially explained by the small group size, the time factor between the trials, habituation of the subjects by trials 3 and 4, the significant F ratio between the four means, and

again, the design of the study (i.e., subjects in Group II were working at individual work loads which were designed to produce a steady state heart rate of approximately 164 beats/min.).

Correlations significantly greater than 0 can be seen between trials 3 and 4 (0.58), trials 1 and 3 (0.61), trials 2 and 3 (0.70) and trials 1 and 2 (0.78). One would anticipate these higher correlations in the first two instances due to less time between trials and the habituation of subjects for trials 3 and 4. The higher correlations between trials 2 and 3, and trials 1 and 2, would not be expected, however, due to the stress factor. This may be partially explained by the proximity in time of the tests, and perhaps indicate that the stress administered in trial 2 had even less an effect on the subjects in Group II than the subjects in Group I. This tends to support the contention of Borg and Dahlstrom (20) concerning the reliability of results using heavier work loads. The higher correlation between trials 2 and 3 further suggests that there was no anticipation effect in trial 3 from the test-induced stress as previously indicated for Group I.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the influence of a test induced stress on the prediction of maximal oxygen uptake as determined by the Astrand-Ryhming Nomogram. The variation of results with subjects working at a low work load, producing a steady state heart rate of approximately 138 beats/min., and subjects working at a heavier work load, producing a steady state heart rate of approximately 164 beats/min. was also studied.

Twenty-eight female subjects in second and third year physical education at the University of Alberta, aged 18 to 25 years, made up the sample. Four tests were administered to each subject over a period of 3 to 4 weeks with a minimum of 2 and maximum of 5 days between each test. Each subject was assigned randomly to the low (Group I) or high (Group II) work load group following an initial test. No indication was given to subjects that there would be a test induced stress administered at the beginning of the second trial.

The test itself was performed on a Monarch Bicycle

Ergometer. Subjects rode at a work load calculated to produce a steady state heart rate close to 138 or 164 beats per minute after 6 minutes of exercise. Heart rate was recorded at intervals of 1 minute throughout the test. At the beginning of the second trial a pistol was fired into the air once directly behind the subject's head. The Astrand-Ryhming Nomogram was then used to determine the maximal oxygen uptake for each subject on each trial.

Pearson Product-Moment Correlation Coefficients, a two way analysis of variance repeated on 4 trials, and a one way analysis of variance repeated on four trials provided the basis for the statistical analysis.

The mean steady state heart rates for the four trials for all 28 subjects were as follows: 149.73, 151.07, 147.29, 145.38. For Group I, the results were: 134.14, 136.86, 135.54, 133.07. For Group II, the results were: 165.32, 165.29, 159.04, 157.69. The statistical analysis indicated that there was a significant difference between the means over the four trials for Group II ($P = .01$). This difference was not between the control (trial 1) and stress (trial 2) trials, however, but appeared to be between trials 1 and 3, trials 1 and 4, trials 2 and 3, and trials 2 and 4.

It was further noted that the decrease in mean steady

state heart rates with repeated testing was not as great as that reported by Macnab and Conger (49). This suggested that although the influence of stress did not produce a significant difference in results, perhaps it did have some effect.

The correlation coefficients between the four trials for all 28 subjects indicated a slightly higher correlation between trials 3 and 4, suggesting habituation of the subjects with repeated testing. There was also a slightly lower correlation between trials 2 and 3 suggesting some influence from the stress administered in trial 2 and perhaps some anticipation effect in trial 3.

The results for Group I indicated low correlations between trial 2 and trials 1 and 3; low correlations were also shown between trial 1 and trials 3 and 4. It was pointed out that in this first set of results, a contributing factor was likely the test induced stress administered in trial 2. In the second set of results, habituation on the part of the subjects, the time lapse between trials, and the actual design of the study, were probably contributing factors. The higher correlation between trial 3 and trial 4 also suggests habituation of the subjects by the latter trials.

For Group II, low correlations were reported for trial 1 and trial 4, and trial 2 and trial 4, again suggest-

ing habituation and the influence of the time lapse between trials. Correlations significantly greater than 0 ($P = .01$) were shown between trial 2, and trials 1 and 3, suggesting that the stress factor had very little influence with Group II. The higher correlation between trial 3 and trial 4 ($P = .05$), and trial 2 and trial 3 ($P = .01$) further indicated habituation of the subjects in the latter trials.

It was noted that a general trend of improvement occurred over the 4 trials for both groups indicating a decrease in apprehension with repeated testing. No attempt, however, was made to distinguish between this factor and training and learning effects.

Conclusions

Within the limits of this study, the following conclusions have been made:

1. For the population studied, stress appeared to have no significant influence on the prediction of maximal oxygen intake as measured by the Astrand-Ryhming nomogram.
2. Stress did appear to influence the mean heart rates during the initial period of exercise, however, this influence was abolished before the conclusion of exercise. This influence was more prolonged in the case

of the low work load group.

3. Improvement in prediction occurred with repeated testing of the subjects. No attempt was made to differentiate between training and learning effects. Familiarization of the subjects with the test may have contributed to this improvement.
4. The reliability of this predictive test appeared to be higher with heavier work loads.

Recommendations

During this experiment, several other associated areas of investigation became apparent. Therefore, the following studies are recommended:

1. A study designed to investigate the influence of a more severe stress on the prediction of maximal oxygen uptake.
2. A study to determine the influence of stress administered nearer the completion of exercise.
3. A comparative study of the influence of stress on trained and untrained subjects.
4. A study to investigate the distinction between learning, training, and habituation effects in the improvement in prediction of maximal oxygen intake as determined by the Astrand-Ryhming Nomogram.
5. A study including a separate control group, in order to

compare the normal improvement with repeated testing that occures with the changes that occur when a test-induced stress is administered in one of the trials. Previous studies have indicated greater decreases in mean steady state heart rate values with repeated testing than those reported in this study (especially between trials 1 and 2). This control group would have to be completely separate, perhaps tested in another location, so that if word of the stress should get out, the subjects in the control group would not hear about it.

BIBLIOGRAPHY

1. Adolph, E. F., Physiology of Man in the Desert. New York: Interscience, 1947, pp. 172-207.

2. Anderson, K. L., Hart, J. S., "Aerobic Working Capacity of Eskimos," Journal of Applied Physiology, vol. 18 (1963), pp. 764-768.

3. Asmussen, E., Christensen, E. H., and Neilsen, M., "Die Bedeutung der Korperstellung fur die Pulsfrequenz bie Arbeit," Scandinavica Arch. Physiologica, 81: 190, 1939.

4. Asmussen, E., Hemmingsen, I., "Determination of Maximum Working Capacity at Different Ages in Work with the Legs or with the Arms," Scandinavian Journal of Clinical and Laboratory Investigation, vol. 10 (1958), pp. 67-71.

5. Astrand, I., "Aerobic Work Capacity in Men and Women with Special Reference to Age," Acta Physiologica Scandinavica, vol. 49 (Supplementum 169, 1960), pp. 45-60.

6. Astrand, I., Astrand, P. O., Christensen, E., Hedman, R., "Circulatory and Respiratory Adaptation to Severe Muscular Work," Acta Physiologica Scandinavica, vol. 50 (1960), pp. 254-258.

7. Astrand, I., Astrand, P. O., Rodahl, K., "Maximal Heart Rate During Work in Older Men," Journal of Applied Physiology, vol. 14 (1959), pp. 562-566.

8. Astrand, P. O., Experimental Studies of Physical Working Capacity in Relation to Sex and Age, Copenhagen: Munksgaard, 1952, pp. 23-37, 15-27, 110, 148.

9. Astrand, P. O., "Maximum Working Capacity for the Two Sexes and for Different Age Groups from 41 to 30 Years," Acta Physiologica Scandinavica, vol. 25 (Supplementum 89, 1951), pp. 3-4.

10. Astrand, P. O., "Human Physical Fitness with Special Reference to Sex and Age," Physiological Reviews, vol. 36 (1956), pp. 307-335.

11. Astrand, P. O., Work Tests with the Bicycle Ergometer, AB Cykelfabriken Monark, Varberg, 1965, pp. 1-14.

12. Astrand, P. O., Rhyming, I., "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate During Submaximal Work," Journal of Applied Physiology, vol. 7 (1954), pp. 218-221.

13. Astrand, P. O., Saltin, B., "Oxygen Uptake and Muscular Activity," Journal of Applied Physiology, vol. 16 (1961), pp. 977-981.

14. Balke, B., Grillow, G. P., Korecci, E. B., and Luft, U. C., "Work Capacity After Blood Donation," Journal of Applied Physiology, 7: 231, 1954.

15. Balke, B., Ware, R. W., "An Experimental Study of 'Physical Fitness' of Air Force Personnel," U.S. Armed Forces Medical Journal, vol. 10 (1959), p. 675.

16. Baycroft, G. H., "An Evaluation of the Modified Astrand Ryhming Nomogram as an Estimator of Max. O_2 Consumption." Unpublished Masters' Thesis, University of Alberta, August, 1964.

17. Benedict and Cathcart, Carnegie Publications, No. 187, 1913.

18. Bengtsson, E., "The Working Capacity in Normal Children Evaluated by Submaximal Exercise on the Bicycle Ergometer and Compared with Adults," Acta Medica Scandinavica, 154: 91-109, 1956.

19. Boothby, W. M., American Journal of Physiology, vol. 37 (1915), pp. 383-417.

20. Borg, G., Dahlstrom, H., "The Reliability and Validity of a Physical Work Test," Acta Physiologica Scandinavica, vol. 55 (1962), pp. 353-361.

21. Bourne, P. C., The Psychology and Physiology of Stress. Academic Press: New York and London, 1969. pp. 95.

22. Brouha, L., Heath, C. W., "Resting Pulse and Blood Pressure Values in Relation to Physical Fitness in Young Men," New England Journal of Medicine, vol. 228 (1943), pp. 473.

23. Brouha, L., Smith, P. E., Jr., DeLanne, R., and Maxfield, M. E., "Physiological Reactions of Men and Women During Muscular Activity and Recovery in Various Environments," Journal of Applied Physiology, 16: 133, 1961.

24. Buskirk, E. R., Iampietro, P. F., and Bass, D. E., "Work Performance after Dehydration: Effects of Physical Conditioning and Heat Acclimitization," Journal of Applied Physiology, 12: 189, 1958.

25. Buskirk, E., Taylor, H. L., "Maximal Oxygen Intake and its Relation to Body Composition with Special Reference to Chronic Physical Activity and Obesity," Journal of Applied Physiology, vol. 11 (1957), pp. 72-78.

26. Christensen, E. H., "Beitrage zur Physiologie schwerer korperlicher Arbeit." Arbeitphysiologie, 4: 453, 1956.

27. Cumming, G. R., Danzinger, R., "Bicycle Ergometer Studies in Children," Pediatrics, Vol. 32 (1963), pp. 202-208.

28. Cunningham, D. A., "The Effects of Breathing High Concentrations of Oxygen on Treadmill Performance

and Selected Physiological Variables," Unpublished Masters' Thesis, University of Alberta, Edmonton, August, 1963.

29. Day, J. A., "A Statistical Investigation of the Ryhming Step-Test," Research Quarterly, 38: 539-543, 1966.

30. de Vries, H. A., Klafs, C. E., "Prediction of Maximal Oxygen Intake from Submaximal Tests," Physiology of Exercise Research Laboratory, Long Beach, California, March 1964.

31. Dill, D. B., "Effects of Physical Strain and High Altitude on the Heart and Circulation," American Heart Journal, vol. 23 (1942), pp. 441-454.

32. Dill, D. B., Talbott, J. H., Edwards, H. T., "Response of Several Individuals to a Fixed Task," Journal of Physiology, vol. 69 (1930), p. 267.

33. Edholm, D. G., Adam, J. M., Fox, R. H., "The Effects of Work in Cool and Hot Conditions on Pulse Rate and Body Temperature," Ergonomics, vol. 5 (1962), pp. 545.

34. Erickson, L., Simonson, E., Taylor, H. L., Alexander, H., Keys, A., "The Energy Cost of Horizontal and Grade Walking on the Motor Driven Treadmill," American Journal of Physiology, vol. 145 (1946), p. 391.

35. Fedoruk, D. E., "An Evaluation of Two Versions of the Sjostrand Physical Work Capacity Test," Unpublished Masters' Thesis, University of Alberta, Edmonton, Fall, 1969.

36. Glassford, R. G., "A Comparison of Maximal Oxygen Consumption Values as Determined by Predicted and Actual Techniques," Unpublished Masters' Thesis, University of Alberta, August, 1964.

37. Glassford, R. G., Baycroft, G. H. Y., Sedgewick, A. W., Macnab, R. B. J., "Comparison of Maximal Oxygen Uptake Values Determined by Predicted and Actual Methods," Journal of Applied Physiology, vol. 20 (1965), pp. 509-513.

38. Green, H. J., "A Comparison of the Work Capacity of the Urban and Rural Secondary School Populations in the Province of Alberta as Measured by the Astrand Submax. Bicycle Ergometer Test." Unpublished Masters' Thesis, University of Alberta, August, 1965.

39. Hettinger, T., Birkhead, N. C., Howath, S. M., Issekutz, B., Rodahl, K., "Assessment of Physical Work Capacity," Journal of Applied Physiology, vol. 16 (1961), pp. 153-156.

40. Hill, A. V., Muscular Activity, Baltimore: Williams and Wilkins, 1926, p. 115.

41. Hill, A. V., Long, C. N. H., Lupton, H., "Muscular Exercise, Lactic Acid and Supply and Utilization of Oxygen," Proceedings of the Royal Society of London, Series B., vol. 97 (1925), p. 155.

42. Hyde, R. C., "The Astrand Ryhming Nomogram as a Predictor of Aerobic Capacity for Secondary School Students," Unpublished Masters' Thesis, University of Alberta, Edmonton, May, 1965.

43. Issekutz, B., Jr., Physiologist, vol. 3 (1960), p. 85.

44. Karpovich, P. V., Physiology of Muscular Activity, London: W. B. Saunders Co., 1959.

45. Kjellberg, S. R., Rudhe, U., and Sjostrand, T., "The Amount of Hemoglobin (Blood Volume) in Relation to the Pulse Rate and Heart Volume During Work," Acta Physiologica Scandinavica, 19: 152, 1949.

46. Krogh, H., Lindhard, J., "A Comparison Between Voluntary and Electrically Induced Muscular Work in Man," Journal of Physiology, vol. 51 (1917), pp. 182-201.

47. Krogh, H., and Lindhard, J., "The Relative Value of Fats and Carbohydrates as Sources of Muscular Energy," Biochemical Journal, 14: 290, 1920.

48. Lundgren, N. P. U., "The Physiological Effects of Time Schedule Work on Lumber-Workers," Acta Physiologica Scandinavica - Supplementum 13, vol. 41 (1946), pp. 1-137.

49. Macnab, R. B. J., and Conger, P. R., "Observations on the Use of the Astrand-Ryhming Nomogram in University Women," 13th Annual Convention of the American College of Sports Medicine, Madison, Wisc., March 24, 1966.

50. Master, A. M., Oppenheimer, E. T., "A Simple Exercise Tolerance Test for Circulatory Efficiency with Standard Tables for Normal Individuals," American Journal of Medical Sciences, vol. 177 (1929), pp. 223.

51. Mitchell, J. H., Sproule, B. J., Chapman, C. B., "The Physiological Meaning of the Maximal Oxygen Intake Test," Journal of Clinical Investigation, vol. 37 (1958), pp. 538-546.

52. Newton, J. L., "The Assessment of Maximal Oxygen Intake," Journal of Sports Medicine and Physical Fitness," vol. 3 (1963), pp. 164-169.

53. Robinson, S., "Temperature Regulation in Exercise," Pediatrics - Supplement 32 (1963), pp. 691-702.

54. Robinson, S., Edwards, H. T., Dill, D. B., "New Records in Human Power," Science, vol. 85 (1937), pp. 401-410.

55. Rodahl, K., Astrand, P. O., Birkhead, N., Hettinger, T., Issekutz, B., Jr., Jones, M., Weaver, R., "Physical Work Capacity," American Medical Association Archives Environmental Health, Vol. 2 (1961), pp. 499-510.

56. Rodahl, K., Issekutz, B., Jr., Muscle as a Tissue, Rodahl and Howath, Ed., Toronto: McGraw-Hill Book Co., 1962.

57. Rowell, L. B., Taylor, H. L., Wang, Y., "Limitations to Prediction of Maximal Oxygen Intake," Journal of Applied Physiology, vol. 19 (1964), pp. 919-927.

58. Schneider, E. C., "A Study of Responses to Work on Bicycle Ergometer," American Journal of Physiology, vol. 97 (1931), pp. 353-364.

59. Selye, H., The Stress of Life. McGraw-Hill, N. Y., 1956, p. 47.

60. Shephard, R. J., "The Relative Merits of the Step Test, Bicycle Ergometer and Treadmill in the Assessment of Cardio-Respiratory Fitness," Int. Z. Angew. Physiol. einschl. Arbeitphysiol., 23: 219-230, 1966.

61. Sjostrand, T., "Changes in the Respiratory Organs of Workmen at an Ore Smelting Works," Acta Medica Scandinavica, vol. 196 (Supplement, 1947).

62. Sjostrand, T., "The Total Quantity of Hemoglobin in Man and Its Relation to Age, Sex, Body Weight and Height," Acta Physiologica Scandinavica, vol. 18 (1949), pp. 324-336.

63. Taylor, C., "Effect of Work-Load and Training on Heart Rate," American Journal of Physiology, vol. 135 (1941), pp. 27-42.

64. Taylor, H. L., Buskirk, E., Henschel, A., "Maximal Oxygen Intake as an Objective Measure of the Cardio-Respiratory Performance," Journal of Applied Physiology, vol. 8 (1955), pp. 73-80.

65. Taylor, H. L., Wang, Y., Rowell, L., Blomquist, G., "The Standardization and Interpretation of Submeximal and Maximal Tests of Working Capacity," Pediatrics: Supplementum, vol. 32 (1963), pp. 703-722.

66. von Dobeln, W., "A Simple Bicycle Ergometer," Journal of Applied Physiology, vol. 7 (1954), pp. 222-224.

67. von Dobeln, W., "Maximal Oxygen Intake, Body Size, and Total Hemoglobin in Normal Man," Acta Physiologica Scandinavica, vol. 38 (1957), p. 193.

68. von Dobeln, W., Engstrom, C. G., Strom, G., "Physical Working Capacity of Swedish Air Force Pilots," Journal of Aviation Medicine (Aerospace Medicine), vol. 30 (1959), pp. 162-166.

69. Wahlund, H., "Determination of Physical Working Capacity," Acta Medica Scandinavica, vol. 132 (Supplementum 215, 1948), pp. 9-78.

70. Walker, H. M., Lee, J., Statistical Inference, Henry Holt and Company, N. Y., 1953.

71. Williams, C. G., Bredell, G. A. C., Wyndham, C. H., Strydom, N. B., Morrison, J. F., Peter, J., Fleming, P. W., Ward, J. S., "Circulatory and Metabolic Reactions to Work in Heat." Journal of Applied Physiology, V. 17 (1962), p. 625.

72. Winer, B. J., Statistical Principles in Experimental Design, McGraw-Hill, New York, 1962.

73. Workman, J. M., Armstrong, B. W., "A Nomogram for Predicting Treadmill-Walking Oxygen Consumption," Journal of Applied Physiology, vol. 19 (1964), pp. 150-151.

74. Wyndham, C. H., Strydom, N. B., Maritz, J. S., Morrison, J. F., "Maximum Oxygen Intake and Maximum Heart Rate During Strenuous Work," Journal of Applied Physiology, vol. 14 (1959), pp. 927-936.

75. Zahar, E. W. R., "Reliability and Improvement with Repeated Performance of the Sjostrand Work Capacity Test," Unpublished Masters' Thesis, University of Alberta, July, 1965.

APPENDICES

APPENDIX A

STATISTICAL TREATMENT

Correlation Coefficients. Correlation coefficients between the four trials of predicted maximal oxygen uptake were obtained by use of an IBM-1620 Electronic computer program (DEST 02) at the University of Alberta computer center.

Statement of Problem

Given N sets of observations $(X_{i1}, X_{i2}, \ldots, X_{ip})$, $i = 1, 1, \ldots, N$, on p random variables $X_1, X_2, \ldots, Xp$, it is required to compute

(a) Means, $Xj = \frac{1}{N} \sum_{i=1} Xij, \quad j = 1, 2, \ldots, p$

(b) Variances, $S_j^2 = \frac{1}{N} (\sum X_{ij})^2 \quad j = 1, 2, \ldots, p$

(c) Standard deviations, S_j, $j = 1, 2, \ldots, p$

(d) Correlation Coefficients

$$r_{jk} = \frac{1}{N-1} \frac{\left[\sum_i X_{ij} X_{ik} - \frac{1}{N} \sum_i X_{ij} \sum_i X_{ik}\right]}{S_j S_k}$$

$j = 1, 2, \ldots, p.$

$k = 1, 2, \ldots, p.$

Significance of the Difference Between Two Correlation Coefficients for Correlated Samples. To test the difference between any two correlations based on correlated samples a t value was calculated using the following formula (70:257):

$$t = \frac{(r_{12}-r_{13}) \sqrt{(N-3)\ (1 + r_{23})}}{\sqrt{2\ (1-r_{12}^2 - r_{13}^2 - r_{23}^2 + 2r_{12}r_{13}r_{23}}}$$

The t was tested for significance with N-3 degrees of freedom.

Analysis of Variance. An analysis of variance designed to test the significance of the difference between means obtained from correlated groups (two criteria of classification and repeated on 4 trials) was used in this study (72:302).

(1)

	Subject	b_1	b_2	b_3	Total
a_1	1	X_{111}	X_{121}	X_{131}	P_1
	2	X_{112}	X_{122}	X_{132}	P_2
a_2	3	X_{213}	X_{223}	X_{233}	P_3
	4	X_{214}	X_{224}	X_{234}	P_4
			(ΣX) TOTAL	=	G

(2) Computational Symbols:

(1) G^2/npq

(2) ΣX^2

(3) $(\Sigma A_i^2)/nq$

(4) $(\Sigma B_j^2)/np$

(5) $[\Sigma (AB_{ij})^2]/n$

(6) $(\Sigma P_k^2)/p$

(3) Analysis of Variance

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	(6)-(1)=25069.00	$\frac{np-1}{p-1} = \frac{27}{1}$		
A	(3)-(1)=20304.38		20304.38	110.79
Subjects within groups	(6)-(3)= 4765.00	p(n-1) = 26	183.27	
Within Subjects	(2)-(6)= 2926.00	$\frac{np(q-1)}{q-1} = \frac{84}{3}$		
B	(4)-(1)= 540.75		180.25	6.619
AB	(5)-(3)-(4)+(1)=262.50	(p-1)(q-1)=3	87.50	3.213
B x subjects within groups	(2)-(5)-(6)+(3)=2124.00	p(n-1)(q-1)=78	27.23	

A one way analysis of variance repeated on four trials was used to test the significance of the difference between the means for Group I and then for Group II (72:105).

(1)

	Treatment								
Person	1,	2,	...	j	...	K	Total	Mean
1	X_{11}	X_{12}		X_{ij}		X_{iK}	P_1	$\bar{P}_1$
2	X_{21}	X_{22}		X_{2j}		X_{2K}	P_2	$\bar{P}_2$
.	.	.		.		.	.	.
.	.	.		.		.	.	.
.	.	.		.		.	.	.
i	X_{i1}	X_{i2}		X_{ij}		X_{iK}	P_i	$\bar{P}_i$
.	.	.		.		.	.	.
.	.	.		.		.	.	.
.	.	.		.		.	.	.
n	X_{n1}	X_{n2}	...	X_{nj}	...	X_{nK}	Pn	$\bar{P}n$
Total	T_1	T_2	...	T_j	...	T_K	G	
Mean	$\bar{T}_1$	$\bar{T}_2$	...	$\bar{T}_j$	...	$\bar{T}_K$		$\bar{G}$

(2) Computational Symbols:

(1) G^2/kn

(2) $\Sigma\Sigma\, X^2$

(3) $(\Sigma\, T_j^2)/n$

(4) $(\Sigma\, P_i^2)/n$

(3) Analysis of Variance

A) Group I

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Between People	(4)-(1)=2668.88	n-1 = 13	205.30	
Within People	(2)-(4)=1363.50	n(K-1)=42	32.46	
Treatments	(3)-(1)= 114.25	K-1 = 3	38.08	1.1889
Residual	(2)-(3)-(4)+(1)= 1249.25	(n-1)(K-1)=39	32.03	
Total	(2)-(1)=4032.38	Kn-1 = 55		

B) Group II

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Between People	(4)-(1)=2096.00	n-1 = 13	161.23	
Within People	(2)-(4)=1562.00	n(K-1)=42	37.19	
Treatments	(3)-(1)= 688.00	K-1 = 3	229.33	10.23
Residual	(2)-(3)-(4)+(1)= 874.00	(n-1)(K-1)=39	22.41	
Total	(2)-(1)=3658.00	Kn-1 = 55		

Significance of the Difference Between Two Means for Correlated Samples

$$S_D 2 = \frac{\Sigma D^2}{N-1} - \bar{D}^2$$

$$S_{\bar{D}}^2 = \frac{S_D 2}{N}$$

$$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{\bar{D}}{\frac{S_D 2}{N}}$$

degrees of freedom = N-1

Standard Deviation

$$S = \sqrt{\frac{X^2}{N} - \bar{X}^2}$$

Significance of a Correlation Coefficient

$$t = r\sqrt{\frac{N-2}{1-r^2}}$$

degrees of freedom = N-2

APPENDIX B

INDIVIDUAL SCORE SHEETS

NAME: AGE: HT.: WT.:

ADDRESS: PHONE: SMOKER: GROUP:

TESTING DAYS: TIME: WORK LOAD:

TRIAL	LOAD (KPM)	PRE-EXERCISE HR.	PULSE RATES AFTER MIN. OF WORK							PREDICTED MAXIMAL OXYGEN UPTAKE (litres/min)
			1	2	3	4	5	6	FINAL	
Initial										
1										
2										
3										
4										

APPENDIX C

RAW SCORES

INFORMATION PERTAINING TO INDIVIDUAL SUBJECTS

PHYSICAL CHARACTERISTICS

Subject		Age in Yrs.	Ht. in in.	Wt. in lbs.	Smoker
Gr. I	1	21	61	111	No
	2	21	64	115	No
	3	20	60.5	107	No
	4	20	64.5	113	No
	5	19	65.5	133	No
	6	19	62.5	143	Yes
	7	20	62	124	No
	8	20	62.25	132	No
	9	19	62	115	No
	10	24	62	120	No
	11	19	69	143	Yes
	12	22	64.75	118	No
	13	20	63.25	163	No
	14	20	68	178	No
Gr. II	1	20	69	141	No
	2	21	66	130	No
	3	19	63	119	No
	4	20	63.5	133	No
	5	19	65.5	143	Yes
	6	18	64.5	139	No
	7	20	63.5	130	No
	8	21	67.5	144	No
	9	20	60	105	No
	10	20	66.5	159	Yes
	11	19	67	142	Yes
	12	20	65.75	127	No
	13	19	65	140	No
	14	25	68.5	173	No

PRE-EXERCISE HEART RATES FOR INDIVIDUAL SUBJECTS FOR EACH TRIAL

Subject		Trial 1	Trial 2 Stress Trial	Trial 3	Trial 4
Group I	1	80	88	70	63
	2	107	88	98	87
	3	64	70	91	80
	4	61	68	73	59
	5	105	96	88	82
	6	91	61	67	62
	7	61	74	72	65
	8	71	73	87	76
	9	62	76	68	81
	10	76	64	66	63
	11	67	59	70	66
	12	82	100	82	78
	13	45	65	50	45
	14	45	50	63	57
Group II	1	110	107	80	98
	2	113	71	76	65
	3	92	61	66	82
	4	55	94	57	65
	5	82	65	78	75
	6	71	80	73	76
	7	94	94	71	87
	8	96	85	76	70
	9	60	64	65	50
	10	80	90	65	86
	11	73	113	67	76
	12	78	80	75	63
	13	50	100	69	61
	14	75	90	87	45

MINUTE HEART RATES FOR EACH SUBJECT BEFORE AND DURING INITIAL TRIAL FOR SUBJECTS IN GROUP I (LOW WORK LOAD) IN BEATS PER MINUTE AND PREDICTED MAXIMUM OXYGEN UPTAKE (litres/min)

Subjects	Work Load (KPM)	Rest	Exercise HR at Minute: 1	2	3	4	5	6	Steady State Heart Rate	Predicted Maximal Oxygen Uptake
1	600	100	150	161	164	167	173	173	173	1.88
2	600	125	155	167	170	170	173	170	171	1.93
3	600	69	150	155	155	161	155	158	158	2.2
4	600	69	132	145	155	150	155	158	156.5	2.25
5	600	90	150	150	158	155	155	161	158	2.22
6	600	61	125	138	145	155	155	161	158	2.2
7	600	73	129	141	143	138	153	153	153	2.35
8	600	67	132	145	150	150	155	150	152.5	2.38
9	600	65	130	141	145	150	145	150	147.5	2.53
10	600	55	115	125	132	136	145	145	145	2.6
11	600	58	113	130	130	138	138	144	141	2.75
12	600	58	110	125	125	132	136	141	138.5	2.8
13	600	45	115	129	129	125	132	138	135	3.05
14	600	61	113	125	132	125	127	132	129.5	3.35

MINUTE HEART RATES FOR EACH SUBJECT BEFORE AND DURING INITIAL TRIAL FOR SUBJECTS IN GROUP II (HIGH WORK LOAD) IN BEATS PER MINUTE AND PREDICTED MAXIMAL OXYGEN UPTAKE (litres/min)

Subjects	Work Load (KPM)	Rest	Exercise HR at Minute: 1	2	3	4	5	6	Steady State Heart Rate	Predicted $M\dot{V}O_2$
1	600	78	158	164	164	170	167	176	175	1.85
2	600	80	132	153	167	167	170	173	171.5	1.9
3	600	89	130	141	148	161	161	161	161	2.15
4	600	65	141	141	150	158	155	161	157	2.25
5	600	78	141	150	145	150	161	155	158	2.2
6	600	102	136	141	150	155	155	161	158	2.2
7	600	75	129	143	148	148	155	150	152.5	2.35
8	600	80	141	143	145	148	145	153	150	2.45
9	600	60	132	145	141	145	145	150	147.5	2.55
10	600	83	125	132	136	138	141	141	141	2.75
11	600	90	132	132	132	141	129	141	141	2.75
12	600	64	118	120	129	134	132	136	134	3.1
13	600	64	107	115	120	123	132	129	131	3.25
14	600	74	118	122	120	123	127	129	128	3.4

STEADY STATE HEART RATES FOR INDIVIDUAL SUBJECTS IN GROUP I OVER THE FOUR TRIALS IN BEATS PER MINUTE

Subjects	Work Load (KPM)	TRIALS 1	2 Stress Trial	3	4
1	375	136	134	133	138.5
2	400	141	147.5	132	133
3	450	132	142	135	141
4	450	123.5	123.5	121	117
5	450	138.5	129.5	130.5	132
6	450	133	138.5	125	122.5
7	475	120.5	126	120	120
8	525	141	133	148	139.5
9	525	127.5	151.5	144	143
10	550	136	130.5	134	134
11	575	123.5	129.5	141	130.5
12	600	140.5	150	145	136
13	625	143	133	145	132
14	700	142	147.5	144	144

STEADY STATE HEART RATES FOR INDIVIDUAL SUBJECTS IN GROUP II OVER THE FOUR TRIALS IN BEATS PER MINUTE

Subjects	Work Load (KPM)	1	2 Stress Trial	3	4
1	535	156.5	155	147.5	158
2	550	164	156.5	154	155
3	625	167	155	155	155
4	650	165	173	164	158
5	650	161	154	152.5	151.5
6	650	161	151.5	152.5	147.5
7	675	165.5	167	161	157.5
8	725	167	173	170	154
9	750	168.5	171.5	164	159.5
10	800	168	173	150	154
11	800	174.5	180	164	161
12	900	162.5	161	158	159.5
13	950	173	184	173	173
14	1000	161	159.5	161	164

PREDICTED MAXIMAL OXYGEN UPTAKE FOR INDIVIDUAL SUBJECTS OVER THE FOUR TRIALS IN LITRES PER MINUTE

Subject	1	2 (Stress)	3	4
Group I				
1	1.95	2.0	2.05	1.9
2	1.9	1.75	2.2	2.18
3	2.45	2.1	2.35	2.12
4	2.85	2.85	3.0	3.3
5	2.2	2.55	2.5	2.45
6	2.4	2.2	2.8	2.9
7	3.2	2.85	3.25	3.25
8	2.45	2.75	2.2	2.5
9	3.05	2.13	2.35	2.37
10	2.8	3.0	2.85	2.85
11	3.6	3.2	2.65	3.15
12	2.76	2.45	2.6	3.0
13	2.8	3.3	2.7	3.3
14	3.2	2.9	3.1	3.1
Group II				
1	2.05	2.1	2.26	2.0
2	1.9	2.1	2.15	2.13
3	2.1	2.4	2.4	2.4
4	2.2	2.05	2.22	2.4
5	2.3	2.5	2.55	2.6
6	2.3	2.6	2.55	2.7
7	2.25	2.24	2.4	2.5
8	2.4	2.25	2.35	2.8
9	2.44	2.38	2.56	2.7
10	2.6	2.5	3.2	3.1
11	2.45	2.35	2.7	2.8
12	3.1	3.2	3.3	3.22
13	2.9	2.62	2.9	2.9
14	3.5	3.6	3.5	3.4

MINUTE HEART RATES FOR EACH SUBJECT BEFORE AND DURING TRIAL 1 IN BEATS PER MINUTE

Subject Number	Pre-Exercise	Exercise Heart Rate at: 30 sec	1 min	2 min	3 min	4 min	5 min	6 min
Group I								
1	80		118	130	130	129	136	136
2	107		141	136	138	141	141	141
3	64		125	129	129	129	132	132
4	61		105	113	114	118	125	122
5	105		136	136	136	141	141	136
6	91		129	132	136	136	132	134
7	61		105	115	115	115	118	123
8	71		129	136	141	136	141	141
9	62		113	118	125	129	125	130
10	76		122	125	134	138	132	136
11	67		105	110	113	118	122	125
12	82		118	130	136	138	138	143
13	45		122	125	132	136	141	145
14	45		127	138	143	145	141	143
Group II								
1	110		143	150	161	155	158	155
2	113		136	153	161	167	164	164
3	92		141	155	158	161	164	170
4	55		138	155	161	161	164	167
5	82		143	150	150	155	161	161
6	71		129	145	155	155	161	161
7	94		141	155	161	164	164	167
8	96		155	158	161	167	167	167
9	60		145	153	161	164	167	170
10	80		155	155	161	164	167	170
11	73		145	155	164	170	173	176
12	78		141	150	153	155	164	161
13	50		136	155	161	173	173	173
14	75		141	155	153	155	161	161

MINUTE HEART RATES FOR EACH SUBJECT BEFORE AND DURING TRIAL 2 (STRESS TRIAL) IN BEATS PER MINUTE

Subject Number	Pre-Exercise	Exercise Heart Rate at: 30 sec	1 min	2 min	3 min	4 min	5 min	6 min
Group I								
1	88	122	129	130	132	127	132	136
2	88		141	141	141	141	145	150
3	70	125	134	145	145	138	143	141
4	68	107	118	118	122	118	122	125
5	96	117	127	129	125	122	129	130
6	61	105	117	129	132	132	141	136
7	74	107	110	115	125	125	125	127
8	73	114	127	129	134	129	132	134
9	76	103	130	136	141	145	150	153
10	64	107	115	127	127	129	129	132
11	59	107	110	118	118	129	125	134
12	100	118	132	141	145	150	150	150
13	65	105	110	118	125	127	132	134
14	50	113	132	141	145	145	145	150
Group II								
1	107	118	141	145	150	155	155	155
2	71	105	129	132	145	150	155	158
3	61		132	141	150	150	155	155
4	94	120	145	161	161	173	173	173
5	65	136	150	150	155	155	153	155
6	80	122	132	138	145	145	153	150
7	94	136	153	161	161	161	167	167
8	85		155	161	167	170	173	173
9	64	132	148	155	161	164	170	173
10	90	136	155	161	167	167	173	173
11	113		161	167	173	180	180	180
12	80	115	134	145	153	155	161	161
13	100	141	150	164	167	173	184	184
14	90	132	150	145	148	155	158	161

MINUTE HEART RATES FOR EACH SUBJECT BEFORE
AND DURING TRIAL 3 IN BEATS PER MINUTE

Subject Number	Pre-Exercise	Exercise Heart Rate at: 30 sec	1 min	2 min	3 min	4 min	5 min	6 min
Group I								
1	70	117	127	125	129	123	134	132
2	98		129	129	118	129	132	132
3	91	115	130	129	122	132	134	136
4	73	100	118	117	118	122	120	122
5	88	122	129	129	125	136	132	129
6	67	98	113	117	115	120	127	123
7	72	102	110	115	105	113	118	122
8	87	129	136	141	145	143	148	148
9	68	106	120	132	132	132	143	145
10	66	107	111	123	129	125	136	132
11	70	98	113	125	132	141	141	141
12	82	110	123	132	141	138	145	145
13	50	108	118	129	132	141	145	145
14	63	108	125	132	138	145	143	145
Group II								
1	80	115	136	141	141	145	145	150
2	76	115	129	141	143	153	153	155
3	66	118	129	145	150	150	155	155
4	57	125	143	148	155	161	164	164
5	78	129	141	145	150	150	155	150
6	73	120	134	145	145	148	150	155
7	71	129	145	155	153	161	161	161
8	76		150	158	161	164	170	170
9	65	129	155	150	155	161	161	167
10	65	120	141	141	145	145	150	150
11	67	129	141	150	155	161	164	164
12	75	122	134	145	148	155	155	161
13	69		138	155	158	167	173	173
14	87	132	145	153	155	161	161	161

MINUTE HEART RATES FOR EACH SUBJECT BEFORE AND DURING TRIAL 4

			Exercise Heart Rate at:					
Subject Number	Pre-Exercise	30 sec	1 min	2 min	3 min	4 min	5 min	6 min
Group I								
1	63		122	129	129	138	136	141
2	87		132	129	125	132	134	132
3	80		136	138	141	141	141	141
4	59		110	114	113	110	115	117
5	82		129	132	129	132	132	132
6	62		107	98	120	122	120	125
7	65		107	115	114	118	118	122
8	76		125	132	136	132	138	141
9	81		129	136	141	141	141	145
10	63		117	123	125	129	132	136
11	66		113	115	122	130	132	129
12	78		115	122	132	129	134	138
13	45		107	122	129	129	132	132
14	57		129	145	141	141	143	145
Group II								
1	98		145	153	158	155	158	158
2	65		122	132	128	141	141	155
3	82		132	145	150	155	155	155
4	65		143	150	150	155	155	161
5	75		141	150	145	136	145	150
6	76		132	136	141	150	145	150
7	87		129	145	150	155	155	161
8	70		145	141	141	143	153	155
9	50		132	145	143	145	158	161
10	86		138	143	145	143	153	155
11	76		145	155	155	158	161	161
12	63		141	150	150	161	155	164
13	69		138	155	158	167	173	173
14	45		138	155	158	164	164	164

APPENDIX D

CALCULATION OF INDIVIDUAL SUBJECT'S WORK LOAD

The Calculation of the Individual Subject's Work Load

In order to calculate the work load which would produce a steady state heart rate of approximately 138 beats/min. for the subjects in Group I and 164 beats/min. for the subjects in Group II, it was necessary to determine the steady state heart rate achieved by each subject working at an initial work load of 600 KPM. If S = steady state heart rate (at 600 KPM) and d = desired heart rate (i.e., close to either 138 beats/min. or 164 beats/min.), then it is possible to compute the desired work load using the following formula:

$$\text{Work Load} = \frac{d \times 600}{S}$$